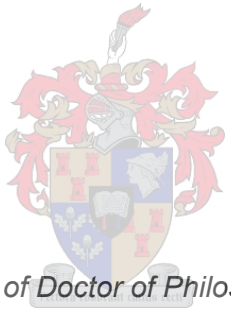
Evaluating the Successful and Sustainable Implementation of Evidence-based Innovations in Health Systems in Low- and Middle-income Countries: A Maturity Model Approach

by

Elizabeth Leonard



Dissertation presented for the degree of Doctor of Philosophy in the Faculty of Engineering at Stellenbosch University.

Supervisor: Prof Imke. H. de Kock
Co-supervisor: Prof Wouter. G. Bam

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Declaration

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Abstract

The unsuccessful and unsustainable implementation of evidence-based health innovations frequently occurs, leading to missed opportunities that could have improved various aspects of a health system. Understanding the facilitators and barriers to the implementation of innovations is especially important in the low- and middle-income country (LMIC) context, where unsuccessful implementation practices impede the progress and improvement of health systems. While high-income countries and LMICs experience many of the same implementation facilitators and barriers, LMICs must deal with additional health system complexities that impact implementation.

Improving the success and sustainability of innovation implementation has become one of the most apparent promoters of LMIC health system improvements. However, existing approaches aimed at facilitating the innovation implementation process either do not consider a holistic health innovation landscape and thus overlook key concepts; or have not specifically been developed for the LMIC context and thus do not adequately capture the contextual specificities of LMICs. To address this gap, a novel solution is developed in this study – the LMIC Health Innovation Implementation Maturity Model (HII-MM).

The research strategy followed in this study is based on the design science strategy. Design science can be divided into three overarching phases: Exploratory, Formative and Evaluative Phases. During the Exploratory Phase, the specific problem and resulting objectives are investigated through three sets of literature reviews: conceptual, systematic, and comparative literature reviews. During the Formative Phase, the solution to the identified problem is developed, namely the HII-MM. Lastly, during the Evaluative Phase, the developed solution is iteratively refined through theoretical and structural verification strategies, and the HII-MM's efficacy in solving the identified problem is validated.

The HII-MM is a maturity assessment tool that facilitates the assessment of LMIC health innovation landscapes. It defines the system's current implementation maturity, identifies gaps hindering an innovation's successful and sustainable implementation, and provides potential maturation paths that can inform improvement initiatives. The HII-MM is made up of three dimensions: (i) implementation domains, which describe the concepts that act as either facilitators or barriers when implementing an evidence-based innovation within an LMIC health system, (ii) health system levels, which portray the health system that is being assessed, and (iii) maturity levels, which are statements that enable the understanding of the system's capability to implement an innovation.

To verify the HII-MM subject matter expert (SME) interviews and a case study on a mHealth audiology device was leveraged. Then, to validate the HII-MM, additional SME interviews were conducted with expert representation from 25 unique LMICs and two case studies were carried out. The first case study is on the maternal health innovation MomConnect and the second is on the contact tracing innovation COVID Alert. These validated the transferability, flexibility, usefulness, and usability of the HII-MM.

This study contributes to the growing literature that aims to inform health system stakeholders in LMICs on successfully and sustainably implementing evidence-based health innovations. The study promotes greater access to evidence-based health innovations to encourage health equity and improve the performance of LMIC health systems.

Opsomming

Die implementering van bewysgebaseerde gesondheidsinnovasies is dikwels onsuksesvol en onvolhoubaar, wat daartoe lei dat geleenthede wat verskeie aspekte van ’n gesondheidstelsel kon verbeter het, misgeloop word. Dit is veral belangrik om die fasiliteerders van en struikelblokke vir die implementering van innovasies in die konteks van die lae- en middel-inkomsteland (LMIL) te verstaan, waar onsuksesvolle implementeringspraktyke die vordering en verbetering van gesondheidstelsels belemmer. Hoewel hoë-inkomstelande en LMIL’e baie van dieselfde implementeringsfasiliteerders en-struikelblokke ervaar, het LIML’e ook nog te doen met bykomende kompleksiteite van die gesondheidstelsel, wat implementering beïnvloed.

Die verbetering van die sukses en volhoubaarheid van innovasie-implementering het een van die mees ooglopende bevorderaars van gesondheidstelselverbeterings in LMIL’e geraak. Die bestaande benaderings, wat daarop gemik is om die innovasie-implementeringsproses te fasiliteer, neem egter óf nie ’n holistiese gesondheidsinnovasielandskap in ag nie en sien dus sleutelkonsepte oor; óf is nie spesifiek vir die LMIL-konteks ontwikkel nie en lê dus nie die kontekstuele spesifisiteite van die LMIL’e genoegsaam vas nie. Om hierdie gaping te oorbrug, is ’n nuwe oplossing in hierdie studie ontwikkel – die LMIL Gesondheidsinnovasie-implementeringsvolwassenheidsmodel (GII-VM).

Die navorsingstrategie van hierdie studie is gegrond op die ontwerpwetenskapstrategie. Ontwerpwetenskap kan in drie oorkoepelende fases verdeel word: die verkennings-, vormings- en evalueringsfases. Tydens die verkenningsfase word die spesifieke probleem en die gevolglike doelwitte deur drie stelle literatuuroorsigte ondersoek: die konseptuele, stelselmatige en vergelykende literatuuroorsig. Tydens die vormingsfase word die oplossing vir die geïdentifiseerde probleem ontwikkel, naamlik die GII-VM. Laastens, tydens die evalueringsfase word die ontwikkelde oplossing herhaaldelik verfyn deur middel van teoretiese en strukturele bevestigingstrategieë en die GII-VM se doeltreffendheid met die oplos van die geïdentifiseerde probleem word gestaaf.

Die GII-VM is ’n volwassenheidsassesseringshulpmiddel wat die assessering van die gesondheidsinnovasielandskap van LMIL’e fasiliteer; dit omskryf die stelsel se huidige implementeringsvolwassenheid, identifiseer gapings wat die suksesvolle en volhoubare implementering van ’n innovasie belemmer, en verskaf potensiële bane vir volwassewording wat verbeteringsinisiatiewe kan onderlê. Die GII-VM bestaan uit drie dimensies: (i) implementeringsdomeine, wat die konsepte beskryf wat as fasiliteerders of hindernisse optree in die implementering van ’n bewysgebaseerde innovasie in ’n LMIL se gesondheidstelsel; (ii) die gesondheidstelselvlakke, wat die gesondheidstelsel wat geassesseer word, uitbeeld; en (iii) volwassenheidsvlakke, of stellings wat dit moontlik maak om die stelsel se vermoë om ’n innovasie te implementeer, te verstaan.

Om die GII-VM te bevestig, is onderhoude met vakdeskundiges (VD’s) en ’n gevallestudie oor ’n mGesondheidtoestel vir oudiologie gebruik. Om die GII-VM te staaf, is bykomende VD-onderhoude gevoer met deskundige verteenwoordigers uit 25 unieke LMIL’e en is twee gevallestudies gedoen. Die eerste gevallestudie is gedoen oor die moedergesondheidsinnovasie, MomConnect, en die tweede oor die kontakopsporingsinnovasie, COVID Alert. Dit het die oordraagbaarheid, buigsaamheid, nuttigheid en bruikbaarheid van die GII-VM gestaaf.

Hierdie studie dra by tot die groeiende literatuur wat daarop gemik is om belanghebbers by die gesondheidstelsel in LMIL'e in te lig oor die suksesvolle en volhoubare implementering van bewysgebaseerde gesondheidsinnovasies. Die studie bevorder groter toegang tot bewysgebaseerde gesondheidsinnovasies om gesondheidsbillikheid aan te moedig en die prestasie van die gesondheidstelsels van LMIL'e te verbeter.

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Nomenclature

AIDS	Acquired immunodeficiency syndrome
ANC	Antenatal care
App. F	Appendix F
CFA	Conceptual Framework Analysis
CFIR	Consolidated Framework for Implementation Research
Chp.	Chapter
CHW	Community health worker
CMM	Capability Maturity Model
COACH	Context Assessment for Community Health
COVID-19	Coronavirus disease 2019
DHIS2	District Health Information System
$E^2RM_{health\ care}$	Economic Enterprise Risk Management in Health Care
eHealth	Electronic health
FAQ	Frequently asked questions
HI-MM	Health Innovation Implementation Maturity Model
HIARAT	Healthcare Innovation Adoption Readiness Assessment Tool
HIC	High-income country
HISPSA	Health Information Systems Programme, South Africa
HIV	Human immunodeficiency virus
HRHCM	High Reliability Health Care Maturity
i-PARIHS	integrated Promoting Action of Research Implementation in Health Services
ID	Identity document
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LMIC	Low- and middle-income country
mHealth	Mobile health
MMEI	Maturity Model for Enterprise Interoperability
MMIC	Maturity Model for Integrated Care
MPCU	Model of Personal Computer Utilization
N/A	Not applicable
NDOH	National Department of Health
NGOs	Non-Governmental Organisation
NHS	National Health Service
NIS	National Innovation System

NPOs	Non-Profit Organisation
OECD	Organisation for Economic Co-operation and Development
PARIHS	Promoting Action of Research Implementation in Health Services
PC	Personal computer
POPIA	Protection of Personal Information Act 4 of 2013
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analysis
R&D	Research and Development
REC	Research Ethics Committee
REP	Replicating Effective Programs
RIS	Regional Innovation System
RUMM	Research Utilisation Maturity Matrix
SCT	Social Cognitive Theory
SDG	Sustainable development goal
SIS	Sectoral Innovation System
SME	Subject Matter Expert
SMS	Short Messaging Service
SU	Stellenbosch University
TAM	Technology Acceptance Model
TB	Tuberculosis
TIS	Technological Innovation System
TM-MAM	Technology Management Maturity Assessment Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UN	United Nations
UNICEF	United Nations Children's Fund
USSD	Unstructured Supplementary Service Data
UTAUT	Unified Theory of Acceptance and Use of Technology
WHO	World Health Organization
Wi-Fi	Wireless Fidelity

Chapter 1 Introduction

The purpose of this chapter is to introduce this study titled *Evaluating the Successful and Sustainable Implementation of Evidence-based Innovations in Health Systems in Low- and Middle-income Countries: A Maturity Model Approach*. First, the background and the rationale for the study are described, guiding the definition of the problem statement. Thereafter, the aim and objectives of the study are specified, and the scope of the research is delimited. The ethical implications of the study are considered, and then an overview is provided of the research outputs resulting from the study. The chapter concludes by outlining the structure of the document.

Chapter 1 Outline:

1.1 BACKGROUND AND RATIONALE

Substantial advances have been made in healthcare over the past few years, and large sums of money have been spent on health innovation (Moses and Martin, 2011; Deloitte, 2017; Wen *et al.*, 2022). However, even with substantial resources committed to and invested in health innovations, these are often not successfully or sustainably implemented in the health system (Denis *et al.*, 2002; Schierhout *et al.*, 2021). This leads to missed opportunities, where various aspects of a health system could have been improved but were not (Yamey, 2012; Jarrett *et al.*, 2022).

Furthermore, the successful implementation of innovations for poorer socioeconomic groups is lower than for their richer counterparts (Atun, 2012; Sangster and Barratt, 2021). Health innovations need to be implemented equitably to prevent the further expansion of access and health disparities (Piot, 2012; Mukherjee, 2021; Shelton *et al.*, 2021; Ukoha *et al.*, 2021; World Health Organization, 2022b). While both high-income countries (HICs) and low- and middle-income countries (LMICs) experience many of the same implementation facilitators and barriers, LMICs have to deal with additional health system complexities that impact implementation, including corruption, high disease burdens and extensive resource shortages (World Health Organization, 2007b; Matlin and Samuels, 2009; Vedanthan, 2011; Bergström *et al.*, 2015; Rispel, 2015; Puchalski Ritchie *et al.*, 2016; Bolan *et al.*, 2021; Glynn, Amukele and Vian, 2021; Kalbarczyk *et al.*, 2021; Tagoe *et al.*, 2021; Whitehorn *et al.*, 2021).

Improving the success and sustainability of innovation implementation has become one of the most apparent promoters of LMIC health system improvements (Hamel and Schrecker, 2011; World Health Organization, 2020a; Korto *et al.*, 2022), which is highlighted by the following examples:

i. The improved implementation of affordable curative and preventative innovations correlates with the reduction of child and maternal mortality; between 2000 and 2017, maternal mortality rates decreased by 38% (Chopra *et al.*, 2012; World Health Organization, 2019b);
ii. In sub-Saharan Africa, mortality from measles was reduced by 92% during the period between 2000 and 2008 as a result of the expanded coverage of the measles vaccination (Yamey, 2012);
iii. Similarly, the implementation of the RTS, S/AS01 malaria vaccine, which was recommended by the World Health Organization (WHO) in October 2021 for expanded use, is predicted to avert between 40 000 to 80 000 additional childhood malaria deaths on the African continent every year (World Health Organization, 2022a);
iv. By successfully implementing the simple innovation of using insecticide-treated bed nets, the occurrences of childhood malaria are estimated to reduce by 50% (Yamey, 2012); and
v. The mass roll-out of the COVID-19 vaccines in LMICs is estimated to have prevented over 8 million COVID-19 deaths between December 2020 and December 2021 (Watson *et al.*, 2022).

The healthcare landscape is generally complex (Heesterbeek *et al.*, 2015; Cassidy *et al.*, 2022), with new (often disruptive) opportunities, legislatures, challenges and diseases constantly arising (Akenroye, 2012; Cohen and Flood, 2022). Such unstable operating conditions need innovation (Akenroye, 2012; World Health Organization, 2022b) for health systems to adapt adequately and remain effective amidst constant changes. The benefits of successfully and sustainably implementing evidence-based health innovations, particularly in LMIC contexts, are clear (Gupta *et al.*, 2016; Leonard, De Kock and Bam, 2020a). Implementation is thus an important mechanism if equitable access to healthcare is to be achieved globally (Bergström *et al.*, 2015; Frisch, Scott and Binagwaho, 2021). However, implementing innovations in a health system is a complex process (Chaudoir, Dugan and Barr, 2013).

The barriers to implementing innovations in healthcare can occur at several levels, including at the patient level, departmental level, healthcare organisational level or policy level (Damschroder *et al.*, 2009; Leonard, De Kock and Bam, 2019b). These barriers can hinder the successful implementation of an innovation and the sustainability of an adopted innovation. Understanding the facilitators and barriers to implementing innovations is especially important in the LMIC context, where unsuccessful implementation practices impede the progress of health systems (Puchalski Ritchie *et al.*, 2016).

Given the importance of successfully and sustainably implementing health innovations in LMICs, this study aspires to contribute towards improving the success and sustainability of health innovations and, more broadly, to contribute to the achievement of the Sustainable Development Goal (SDG) #3: *good health and well-being* (United Nations, 2015). Several existing approaches could be used to support, facilitate, and improve the success and/or sustainability of implementing innovations in LMIC health systems. These approaches tend to fall into one of two research bodies: (i) innovation implementation research, and (ii) implementation science research, which has a health lens. Both of these research areas are discussed in the following sub-sections. In Section 1.1.1, general innovation implementation approaches are considered; thereafter, in Section 1.1.2, health-specific implementation approaches are considered. The existing approaches in these bodies of research cannot effectively support, facilitate, and improve the success and/or sustainability of implementing innovations in LMIC health systems; hence in Section 1.1.3, the hypothesised research gap is further investigated and subsequently confirmed.

1.1.1 Innovation Implementation

In this section, the approaches that exist in innovation implementation research are considered. Innovation implementation approaches stem from behavioural studies research (Momani and Jamous, 2017). Within this field, there are two sub-fields in which innovation implementation approaches have been developed in parallel, namely, (i) psychological studies, in which the well-known Technology Acceptance Model (TAM) was developed, and (ii) social studies, in which the well-known Innovation Diffusion Theory was developed (Momani and Jamous, 2017). A comprehensive view of the foundational innovation implementation approaches is depicted in Figure 1.1.

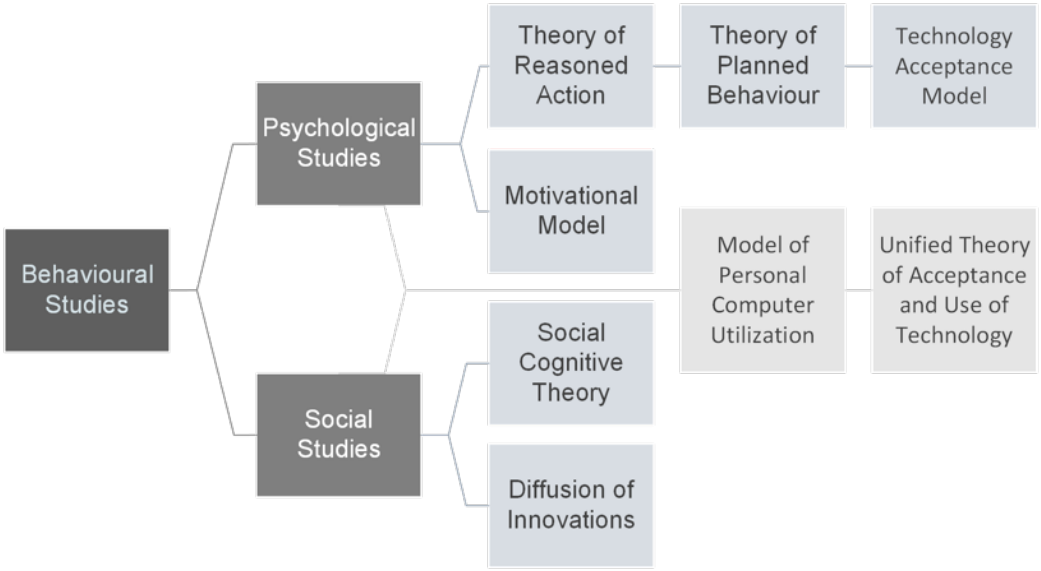

Figure 1.1: Innovation implementation approaches, adapted from Momani and Jamous (2017)

The innovation implementation approaches, as identified by Zolait (2014), Straub (2009), Li (2010), Momani and Jamous (2017), and Taherdoost (2018), are summarised in Table 1.1.

Table 1.1: Innovation implementation approaches

Approach	Description	Foundational Study(s)
Diffusion of innovation	The diffusion theory considers the spread of an innovation through a population and the resulting adoption rate (Rogers, 1995). Within the diffusion of innovation theory, Rogers (1995) defines five variables that affect the rate of adoption of an innovation: (i) perceived attributes of the innovation, (ii) decision type (e.g., authority, collective, optional), (iii) communication channels, (iv) social system characteristics, and (v) extent of promotion efforts.	(Rogers, 1995)
Social Cognitive Theory (SCT)	The SCT, which was developed by Bandura (1986), considers three components that predict the behaviour of individuals and groups: (i) personal attributes, (ii) behavioural aspects, and (iii) environmental factors (Taherdoost, 2018).	(Bandura, 1986)
Motivational Models	Many different models result from motivational theories, attempting to explain why a person makes a specific decision (Bridgeland and Zahavi, 2009; Momani and Jamous, 2017). Motivation models are comprised of two aspects: (i) intrinsic motivation – satisfaction associated with the decision, and (ii) extrinsic motivation – measurable	(Maslow, 1943) (Deci and Ryan, 1985) (Davis, Bagozzi

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Approach	Description	Foundational Study(s)
	outcomes from the decision or behaviour, e.g., financial benefits (Li, 2010; Momani and Jamous, 2017; Taherdoost, 2018)	and Warshaw, 1992)
Theory of Reasoned Action (TRA)	The TRA is the theory from which the TAM originates (Momani and Jamous, 2017). TRA hypothesises that a person's intentions influence his/her behaviour, and that such intentions are determined by (i) beliefs and evaluations, which in turn influence attitudes towards an object or behaviour and (ii) existing societal norms and a person's motivations to comply (Fishbein and Ajzen, 1975; Li, 2010).	(Fishbein, 1967) (Fishbein and Ajzen, 1975)
Theory of Planned Behaviour (TPB)	The TPB is an extension of the TRA, including both behaviours resulting from voluntary and mandatory situations, compared to the TRA, which only considers voluntary situations (Li, 2010). In addition to the two components in the TRA, (i) beliefs and evaluations and (ii) existing societal norms, the TPB include a third component, namely (iii) perceived behavioural control (Ajzen, 1985; Li, 2010).	(Ajzen, 1985)
Technology Acceptance Model (TAM)	The TAM, developed by Davis (1989), is founded on social psychology; it assesses the likelihood of individuals using a technology (Kim *et al.*, 2015). Since the model's introduction in 1989, it has been modified to suit various projects and industries (Kim *et al.*, 2015). The TAM consists of two variables that impact a person's intention to use technology: (i) perceived usefulness and (ii) ease of use. These impact the intention to use and the resulting usage behaviour (Davis, 1989).	(Davis, 1989)
Model of Personal Computer Utilization (MPCU)	The MPCU is derived from Triandis' (1979) theory of attitudes and behaviour; it was developed to understand factors that affect personal computer (PC) use (Thompson, Higgins and Howell, 1991). It is, however, applicable to the adoption of technology more generally. Six factors were identified as influencing PC use, namely: (i) long-term consequences, e.g., improving future opportunities, (ii) job fit, e.g., improving quality of activities performed, (iii) complexity, e.g., being difficult to understand, (iv) promoting use, e.g., increasing interest in tasks, (v) social factors, e.g., other people are using it, and (vi) facilitating conditions, e.g., presence of user guides (Thompson, Higgins and Howell, 1991).	(Thompson, Higgins and Howell, 1991)
Unified Theory of Acceptance and Use of Technology (UTAUT)	UTAUT was developed to explain technology adoption in the workplace (Sovacool and Hess, 2017). The UTAUT is founded on human behaviour theories (Kim *et al.*, 2015). It consists of control variables (gender, age, experience and voluntariness of use), variables influencing behavioural intention (performance expectancy, effort expectancy, social influence) and a variable that directly influences use behaviour (facilitating conditions) (Kim *et al.*, 2015).	(Venkatesh *et al.*, 2003)

The approaches summarised in Table 1.1 do not adequately make use of a systems thinking perspective, nor do they cover the health-specific aspects that influence implementation. Systems thinking is an important part of this study as it considers the context in which a system operates and the system itself as a complex entity of interdependent and interconnected parts (Atun and Memable, 2008), which is particularly important when assessing the LMIC context. Furthermore, these approaches do not address the additional contextual specificities of LMICs. The LMIC contextual specificities are detailed in Chapter 4, and the components present in a health innovation system are detailed in Chapter 3.

1.1.2 Health Innovation Implementation

In this section, the approaches that exist in health innovation implementation research are considered. Health innovation implementation approaches fall into the relatively new research field called *implementation science*, also called *implementation research* (Bauer *et al.*, 2015). Implementation science can be defined as the "*scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services*" (Eccles and Mittman, 2006, p.1). Implementation science is a multi-disciplinary field with roots in numerous disciplines, the earliest of which is innovation implementation research, described in Section 1.1.1.

As portrayed in Figure 1.2, in addition to innovation implementation approaches, implementation science has been influenced by the political sciences research field, namely, policy implementation and the medical research field, namely, the evidence-based movement (Nilsen and Birken, 2020). Implementation science has most frequently been associated with the medical field's advent of the evidence-based movement (Nilsen and Birken, 2020). Policy implementation research addresses the gap between formulating and implementing policies (Smith, 1973; Nilsen and Birken, 2020). Evidence-based medicine considers the active use of research in medicine to bridge the gap between research and medical practices (Guyatt *et al.*, 1992; Nilsen and Birken, 2020). In Appendix A, a selection of 41 health innovation implementation approaches is listed, of which nine are discussed in further detail.

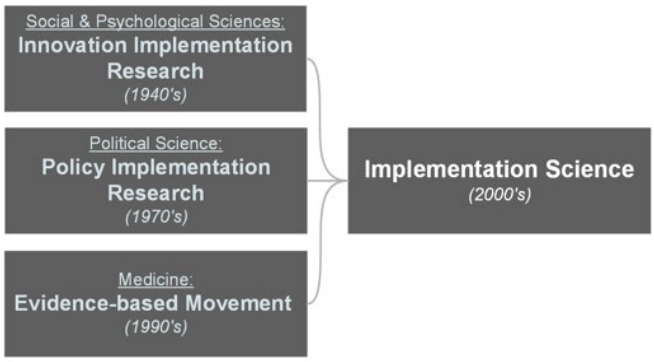

Figure 1.2: Origins of implementation science, adapted from Nilsen and Birken (2020)

In contrast to the innovation implementation approaches, the health innovation implementation approaches incorporate health-specific aspects of implementation. However, these approaches do not holistically cover the innovation system; instead, the approaches tend to focus on specific aspects of an innovation system (Chaudoir, Dugan and Barr, 2013), such as organisational constructs, the behaviour of individual adopters or characteristics of an innovation. Furthermore, most health innovation implementation approaches have been developed in HICs and are not necessarily appropriate for the LMIC context (Means *et al.*, 2020). There are significant differences between HICs and LMICs in terms of culture, context and governance, among other factors, that impact implementation in health systems (Best and Saul, 2011; Ridde, 2016). Thus, the health innovation implementation approaches do not sufficiently address the additional health system complexities of an LMIC context.

1.1.3 Research Gap: Health Innovation Implementation in LMICs

As discussed in Section 1.1.1 and Section 1.1.2, the existing approaches in the respective bodies of research are unable to effectively support, facilitate and improve the success and/or sustainability of implementing innovations in LMIC health systems. Neither the innovation implementation approaches nor the innovation implementation in health systems approaches sufficiently address the LMIC health system context. Furthermore, the innovation implementation approaches do not cover health-specific aspects, and the health innovation implementation approaches do not holistically cover the innovation system.

In the literature, the importance of implementing healthcare innovations has been acknowledged; however, there are still gaps that exist both in literature and in practice (Birken, Lee and Weiner, 2012; Natera, Tomassini and Vera-Cruz, 2019; Marjanovic *et al.*, 2020). The innovation systems approach is a useful analytical tool that promotes a greater understanding of the innovation implementation processes (Edquist, 1997; Morel *et al.*, 2005; Tidd and Bessant, 2009; Dahesh *et al.*, 2020; Lewis, 2021). Consequently, by integrating an innovation systems approach and health systems lens, a greater understanding of and a distinct perspective on the relationships that enable innovation implementation can be attained (Proksch *et al.*, 2019).

Thus, the research gap that this study intends to address is an approach that is applicable to and enables the description of the intricacies of an LMIC context, is multi-dimensional describing and enables an understanding of a health innovation landscape, applies to a variety of evidence-based health innovations, and defines a path towards improving the success and sustainability of innovation implementation. With no appropriate approaches identified during the investigation of existing innovation and health system implementation approaches, it is necessary to confirm whether any other approaches address the identified research gap. To guide the investigation, the intersections of the three overarching themes of this study, as portrayed in Figure 1.3, viz., (i) health innovation, (ii) implementation, and (iii) LMIC context, will be considered.

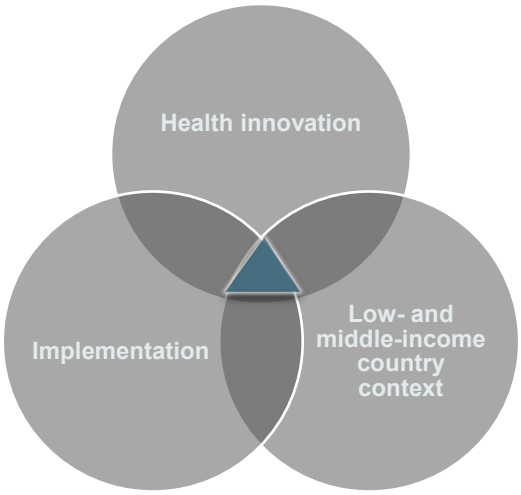

Figure 1.3: Venn diagram showing the themes and focus area of the study

A search was carried out on the Scopus database[1] in October 2022 to confirm whether the hypothesised research gap exists. The search was not restricted by date, field, or study type. The specific search string used is presented in Appendix A; the search string comprises: *LMIC health innovation implementation approach* and relevant synonyms. Using this search string, Scopus returned 18 results. Each result was screened using the following exclusion criteria:

i. No approach is presented or used in the study;
ii. The approach presented is not able to assess an implementation process; or
iii. The approach was not developed for the LMIC context.

After applying the exclusion criteria to the Scopus results, three studies remained. Table 1.2 provides an overview of the remaining studies and the approaches they used or presented.

Table 1.2: Studies included in the selection of an approach, viz., the LMIC health innovation implementation approach

Study	Description of Approach Used / Presented	Study's Reference
Health system context and implementation of evidence-based practices – development and validation of the Context Assessment for Community Health (COACH) tool for low- and middle-income settings	The COACH tool Bergström *et al.* (2015) developed focuses on the context in which an innovation is being implemented. The tool was developed specifically for the LMIC context. The contextual factors measured by the tool are divided into eight components, namely, (i) community engagement, (ii) health workers' commitment, (iii) culture in the health facility, (iv) informal payment mechanisms, (v) leadership, (vi) resources, (vii) service monitoring, and (viii) knowledge sources (Bergström *et al.*, 2015).	(Bergström *et al.*, 2015)
Initiatives supporting evidence-informed health system policymaking in Cameroon and Uganda: A comparative historical case study	Ongolo-Zogo *et al.* (2014) developed the Knowledge Translation Platforms Analytical Framework to improve evidence-informed policy implementation within health systems. The framework comprises three over-arching functions: (i) capacity building, (ii) knowledge management, and (iii) linkage and exchange (Ongolo-Zogo *et al.*, 2014).	(Ongolo-Zogo *et al.*, 2014)
Applying a framework for assessing the health system challenges to scaling up mHealth in South Africa	In this study, Leon, Schneider and Daviaud (2012) develop the Health Systems Framework for decision-making about mHealth for community-based health services. The framework considers four components to assess a mHealth innovation: (i) technological, (ii) financial, (iii) government stewardship, and (iv) organisational (Leon, Schneider and Daviaud, 2012).	(Leon, Schneider and Daviaud, 2012)

The three approaches presented in Table 1.2 provide valuable perspectives to implementation in LMIC contexts; however, none address the hypothesised research gap. The COACH tool, developed by Bergström *et al.* (2015), does not sufficiently encompass the innovation system components, most noticeably lacking features of the innovation being considered for implementation. The Knowledge Translation Platforms Analytical Framework developed by Ongolo-Zogo *et al.* (2014) also does not encompass all the innovation system components, focussing solely on knowledge. The Health Systems Framework developed by Leon, Schneider and Daviaud (2012) has been developed for a specific type of health innovation: mHealth, and thus does not address the research

[1] Scopus boasts the "*largest abstract and citation database of peer-reviewed literature*" (Elsevier, 2017, p.1) and contains extensive international and interdisciplinary literature from a variety of publishers and research fields (Elsevier, 2019).

gap. Furthermore, none of the approaches defines a path towards improving the success and sustainability of innovation implementation. The research gap is further emphasised during the systematic literature review, in Chapter 4 and during the maturity model comparison in Chapter 5. Thus, all evidence gathered during the study suggests that the hypothesised research gap that the study seeks to address exists.

1.2 PROBLEM STATEMENT

LMIC health systems continue to face numerous challenges that strain the system, despite the resources dedicated to creating innovative healthcare solutions. The literature on innovation and healthcare has shown a need to explore and evaluate the role of innovation and health systems in LMICs, insofar as they influence the practical implementation of evidence-based health innovations. This exploration is necessary to identify where systematic weaknesses may exist in health innovation systems and implementation processes regarding the successful and sustainable implementation of innovations. An evaluation method would allow healthcare stakeholders to address and further investigate areas in which improvements are necessary for the successful, sustainable and more frequent implementation of innovative, evidence-based healthcare solutions.

1.3 RESEARCH AIM

This research study aims to develop an assessment approach that facilitates the process of evaluating health innovation systems and their capability to successfully and sustainably implement evidence-based innovations in LMICs, by:

i. Identifying the potential barriers and enablers to implementing a health innovation to enable the identification of specific barriers, facilitators and/or gaps, and to enable the benchmarking of innovations or implementation strategies; and
ii. Defining a maturation path to support users in developing improvement processes, enabling the modification of a health innovation, the adaption of an implementation strategy, or adjustments to health innovation system components.

1.4 RESEARCH OBJECTIVES

To achieve the research aim, three research objectives are defined. Table 1.3 outlines the study's overarching research objectives, corresponding sub-objectives, and the relevant chapters addressing these objectives.

Table 1.3: Research objectives and sub-objectives

	Research Objective	Sub-objectives		Corresponding Chapter(s)
RO.1	To evaluate the implementation of evidence-based innovations in LMIC health systems.	RO.1.1	To identify facilitators and barriers to the successful and sustainable implementation of health innovations in the LMIC context.	Chapter 4
		RO.1.2	To evaluate the literature on health and innovation systems and to define the concepts and paradigms relevant to a generic health innovation system.	Chapter 3

Table continues on next page

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	Research Objective	Sub-objectives		Corresponding Chapter(s)
RO.2	To develop an assessment approach that enables a practical and holistic assessment of the facilitators and barriers to implementation in an LMIC health innovation system.	RO.2.1	Using the research aim and RO.1 to define the requirement specifications that will guide the research product development.	Chapter 5
		RO.2.2	To investigate existing health innovation maturity model approaches	Chapter 5
		RO.2.3	To develop an assessment approach that enables the practical and holistic assessment of the implementation process in LMIC health innovation systems.	Chapter 6 Chapter 7
RO.3	To validate and verify the ability of the proposed approach to practically and holistically assess the facilitators and barriers to implementation present in an LMIC health innovation system.	RO.3.1	To receive inputs from subject matter experts (SMEs) to verify the content and structure of the approach developed in RO.2.	Chapter 8
		RO.3.2	To receive inputs from SMEs to validate the approach's relevance, usefulness, transferability, and usability.	Chapter 9
		RO.3.3	To apply the model to several cases to further validate the approach's usability, usefulness, and flexibility.	Chapter 8 Chapter 9

1.5 RESEARCH SCOPE

The scope of this study is the intersection of the three major literature themes described in Section 1.1, namely: (i) health innovation systems, (ii) implementation science, and (iii) the LMIC context. To achieve the aim and the objectives of the study, an assessment approach is developed within the described intersection. As described by research objective RO.2, the developed approach should enable a practical and holistic assessment of the facilitators and barriers to implementation in an LMIC health innovation system. The formation and evaluation of the assessment approach fall within the study's scope; however, the maintenance of the approach falls outside of the study's scope. The assessment approach, which is developed within the intersection described in Figure 1.3, needs to adhere to the following delimitations:

i. The assessment approach must enable a holistic, systematic assessment of a health innovation system, although lower levels of analysis may still be possible;
ii. The assessment approach must be broadly applicable to a variety of evidence-based innovations and a wide range of LMIC health innovation systems;
iii. The assessment approach must contain a comprehensive view of factors that act as either facilitators or barriers to implementing evidence-based innovations in LMICs;
iv. While the study is focused on the LMIC context, there will be certain principles within the study that are also applicable to HICs;
v. The assessment approach should enable the identification of areas of improvement, although it will not specify an improvement process or an implementation process; and
vi. The developed assessment approach will not guarantee improvements due to the dynamic nature of health innovation systems; however, it does aim to outline a maturation path to improve the implementation capability of the system.

1.6 ETHICAL CONSIDERATIONS

When working with human subjects, it is important to obtain the necessary ethics approvals from a reputable Research Ethics Committee (REC) (Bain, 2018). As the latter part of this study involved human subjects (refer to research objectives RO.3 in Section 1.4), ethical clearance was received from the Stellenbosch University REC: Social, Behavioural and Education Research[2].

Before engaging with subject-matter experts for the validation, verification and case study interviews, ethical approval was received from the Stellenbosch University REC. The REC ethics code for this study is: ING-2019-8927. The notice of ethical approval from the REC is presented in Section B.1 in Appendix B. Before each interview, informed consent was obtained from the research participants. The informed consent template used for the subject matter expert (SME) interviews is presented in Section B.2 in Appendix B. Additional ethical approval was sought for the electronic survey used as a data collection tool for the COVID Alert validation case study (refer to Chapter 9 Section 9.3.3). The notice of ethical approval from the REC for the survey is presented in Section B.3 in Appendix B. Before a potential survey participant proceeded to reply to the survey questions, the participant would be required to provide their informed consent to participate in the study. The informed consent template for the survey participants is presented in Section B.4 in Appendix B.

The contents of the informed consent forms presented to potential participants include: (i) an overview of the study, (ii) the data collection procedures that the participant would be engaged with (semi-structured interviews or surveys), (iii) the approximate time requested from the participant, (iv) any potential risks or benefits, (v) the participant's right to withdraw at any point in the study and the voluntary nature of the study, (vi) the confidentiality measures put in place by the investigator, and (vii) the data storage procedures followed by the investigator. The ethical guidelines followed during this study are in accordance with the ethical guidance provided by the Stellenbosch University REC.

1.7 RESEARCH OUTPUTS

The research outputs of this study are described in Table 1.4. The research outputs include publications in two journal articles and publications in three conference proceedings. Table 1.4 lists the reference chapter on which the respective publications are based, the publication title, a brief description of the article and a reference where the publication can be found.

Table 1.4: Publications resulting from the study

Reference Chapter	Publication	Description	Publication Reference
Chapter 8	Investigating the barriers and facilitators to implementing an eHealth innovation in a resource-constrained setting: A South African case study	This publication was presented at and published in the 2020 IEEE International Conference on Engineering, Technology and Innovation proceedings. The publication covers the case study described in Section 8.3. The paper contributes to "*knowledge on health innovation*	(Leonard, De Kock and Bam, 2020b)

Table continues on next page

[2] http://www.sun.ac.za/english/research-innovation/Research-Development/integrity-ethics/human-research-(humanities)-ethics

Table continued from previous page

Reference Chapter	Publication	Description	Publication Reference
		management and promotes improved access to eHealth" (Leonard, De Kock and Bam, 2020b, p.1)	
Chapter 4	Barriers and facilitators to implementing evidence-based health innovations in low- and middle-income countries: A systematic literature review	This publication was published in the *Evaluation and Program Planning Journal*. The publication covers the systematic literature review results presented in Section 4.3. The paper contributes to "*the growing literature that aims to inform health system planners and evaluators in LMICs on effectively and sustainably implementing evidence-based health innovations*" (Leonard, De Kock and Bam, 2020a, p.1)	(Leonard, De Kock and Bam, 2020a)
Chapter 3	Investigating the relationships between health and innovation systems to guide innovation adoption	This publication was presented at and published in the 2019 IEEE International Conference on Engineering, Technology and Innovation proceedings. The publication covers the integration of health and innovation system concepts to develop the conceptual health innovation system framework, as described in Section 3.4.	(Leonard, De Kock and Bam, 2019a)
Foundational work	The development of a healthcare innovation adoption readiness assessment tool (HIARAT)	This publication was published in the *South African Journal of Industrial Engineering* and presented at the 12th Annual Conference on the Science of Dissemination and Implementation in Health. This publication presents the author's foundational work that took place before this research study's commencement. The foundational research considered the implementation of innovations in public healthcare facilities in South Africa.	(Leonard, De Kock and Bam, 2019b)
Chapter 3	The development of a health system framework to guide the analysis of innovation adoption in low- and middle-income countries	This publication was presented at and published in the Southern African Institute for Industrial Engineering 29 conference proceedings. The publication investigates the plethora of health system frameworks described in Section 3.2. The paper contributes to the "*field of health systems engineering by providing an extensive list of existing health system frameworks and by providing a framework that combines the major aspects of a health system to thoroughly and completely describe health systems*" (Leonard, De Kock and Bam, 2018, p.1)	(Leonard, De Kock and Bam, 2018)

1.8 DOCUMENT OUTLINE

Table 1.5 provides an overview of the document outline, which includes the title of each chapter and a succinct summary of each chapter.

Table 1.5: Summary of the document outline

Chapter	Chapter Summary
Chapter 1: Introduction	The purpose of this chapter is to introduce the study. The research gap that the study aims to address is considered, the study's problem statement, aim, objectives and scope are defined, and the ethical implications of the study are discussed.
Chapter 2: Research Approach	The purpose of this chapter is to describe the research approach followed to achieve the study's aim and objectives. The research approach is first considered from a philosophical perspective, and thereafter the specific research design and strategy are defined.
Chapter 3: Research Contextualisation: Health and Innovation Systems	The purpose of this chapter is to investigate the theoretical concepts relevant to health systems and innovation systems, as well as to establish the relationships between health and innovation systems.
Chapter 4: Health Innovation Implementation in LMICs: A Systematic Literature Review	This chapter's purpose is to investigate the barriers and facilitators to implementing evidence-based health innovations in LMIC contexts. To achieve this, a systematic literature review results is conducted. The systematic literature review is used to answer the question: *What are the facilitators and barriers to implementing health innovations in LMICs?* The results are illustrated in the form of a cause-effect diagram.
Chapter 5: Requirement Specifications for the LMIC Health Innovation Implementation Assessment Approach	The purpose of this chapter is to develop requirement specifications for a solution to the identified problem. Based on these requirement specifications, maturity models were identified as an appropriate approach, and existing maturity models were investigated.
Chapter 6: The LMIC Health Innovation Implementation Maturity Model	The purpose of this chapter is to follow the maturity model development process to generate the HII-MM. The development process consists of three steps: plan, populate and evaluate.
Chapter 7: Operationalising the LMIC Health Innovation Implementation Maturity Model	The purpose of this chapter is to operationalise the developed HII-MM.
Chapter 8: HII-MM Verification and Refinement	The purpose of this chapter is to describe the HII-MM verification and refinement process followed. The chapter presents the results of the verification semi-structured interviews and the verification case study.
Chapter 9: HII-MM Validation	The purpose of this chapter is to describe the HII-MM validation process followed. The chapter presents the results of the validation semi-structured interviews and the two validation case studies.
Chapter 10: Summary and Conclusions	This chapter concludes the study by providing an overview of the research conducted, revisiting the research objectives of the study, outlining the original contributions offered throughout the study, and identifying areas for future research.

1.9 CHAPTER 1: CONCLUSION

In this chapter, the research study was introduced. The background and rationale of the study were discussed, and the study's problem statement, aim and objectives were defined. The scope and ethical implications of the study were considered, and the research outputs and document structure were outlined. In the next chapter, the specific research approach followed to achieve the aim and objectives of the study is described.

Chapter 2 Research Approach

Chapter 1 outlined the need to assess LMIC health systems to promote the sustainable implementation of evidence-based health innovations. This chapter provides a description of the research approach followed to achieve the study objectives and develop the LMIC Health Innovation Maturity Model (HII-MM). First, the philosophical perspective of the research is considered, and thereafter the research design and strategy are described. The proposed research strategy, Design Science, is described in three parts. Part 1 of the methodology, the Exploratory Phase, is described in Section 2.3.1 and comprises collecting and categorising data. Part 2 of the methodology, the Formative Phase, is described in Section 2.3.2 and involves the synthesis and integration of data to develop a model. Part 3 of the methodology, the Evaluative Phase, is described in Section 2.3.3 and consists of validating and rethinking the developed model. Lastly, the specific research methodologies used to conduct the study are described.

Chapter 2 Outline:	i.	Philosophical Perspective	..... p.13
	ii.	Research Design	..... p.14
	iii.	Research Strategy	..... p.15

2.1 PHILOSOPHICAL PERSPECTIVE

Research philosophy is the "*system of beliefs and assumptions about the development of knowledge*" (Saunders, Lewis and Thornhill, 2019, p.130). When contributing to a research field through the development of knowledge, as is the aim of this study, it is important to consider the philosophical perspective of the research. This can be defined using three sets of assumptions made by the researcher. These assumptions are: (i) ontological, covering the assumptions about reality; (ii) epistemological, comprising the assumptions made about knowledge and what is known; and (iii) axiological, including the researcher's own intuitions, values and biases (Žukauskas, Vveinhardt and Andriukaitienė, 2018; Saunders, Lewis and Thornhill, 2019). The specific ontological, epistemological, and axiological assumptions can be used to identify the research philosophy pertaining to a particular study. Three primary research philosophies will be considered further, namely:

i. Positivism: is described as an objective philosophy in which data are collected through primarily quantitative methods to create an unbiased view of reality (Bryman and Bell, 2011; Žukauskas, Vveinhardt and Andriukaitienė, 2018; Saunders, Lewis and Thornhill, 2019);
i. Interpretivism: is the opposing philosophy to positivism. Interpretivism focuses on the subjective nature of research, arguing that humans cannot be studied in the same manner as objects or physical phenomena (Bryman and Bell, 2011; Saunders, Lewis and Thornhill, 2019); and
ii. Pragmatism: does not stipulate that one specific methodology or knowledge source should be used; thus, within the research philosophy of pragmatism, the research question is used to determine the appropriate methods, which may entail the use of objective or subjective methods, or a mixed-methods approach (Žukauskas, Vveinhardt and Andriukaitienė, 2018; Saunders, Lewis and Thornhill, 2019).

The philosophical perspective used in this study is pragmatism because the set of ontological, epistemological, and axiological assumptions of pragmatism are in line with the problem statement, aim, objectives and scope of the study. The ontology of pragmatism is that reality is complex and ambiguous and results from the interactions between numerous factors, including between experiences, processes, history and practices (Žukauskas, Vveinhardt and Andriukaitienė, 2018; Saunders, Lewis and Thornhill, 2019). Within the scope of this study (Section 1.5), the need for a systems approach is emphasised, and the scope of the study includes the implementation of innovations in health innovation systems, which are inherently complex. Health systems, and by extension health innovation systems, display the features found in complex dynamic systems; a system outcome is the result of the interactions between a system's elements, not just the result of changes in or to a single element (Atun and Memable, 2008).

The epistemology of pragmatism is knowledge being used to enable actions, with a focus on problem solving, while the axiology of pragmatism is value-driven research (Saunders, Lewis and Thornhill, 2019). The aim and objectives of this study (Sections 1.3 and 1.4) complement the epistemology and axiology of pragmatism. The aim of the study is to develop an assessment approach that can evaluate health innovation systems and their capability to successfully and sustainably implement evidence-based innovations in LMICs. Furthermore, research objective RO.3.2 stipulates the need to ensure that the approach developed is usable and useful. The mixed-methods approach described in the next section, research design, further confirms the appropriateness of pragmatism as the research philosophy for this study.

2.2 RESEARCH DESIGN

Studies can be categorised according to their approach and the data collection methods (Mouton, 2001). As shown in Figure 2.1, a research approach can range from empirical to non-empirical, and the data collected can be classified into primary or secondary data (Mouton, 2001). Empirical research is centred around understanding real-life phenomena using observation and measurement techniques, such as surveys, modelling or simulation, field experiments or participatory research (Mouton, 2001; Emerald Publishing, 2021). In contrast, non-empirical research tends to be more theoretical, ranging from systematic reviews, meta-analyses, conceptual studies, to philosophical analyses (Mouton, 2001; Dan, 2017). Figure 2.1 shows the position of this study in relation to the approach and data collection methods used.

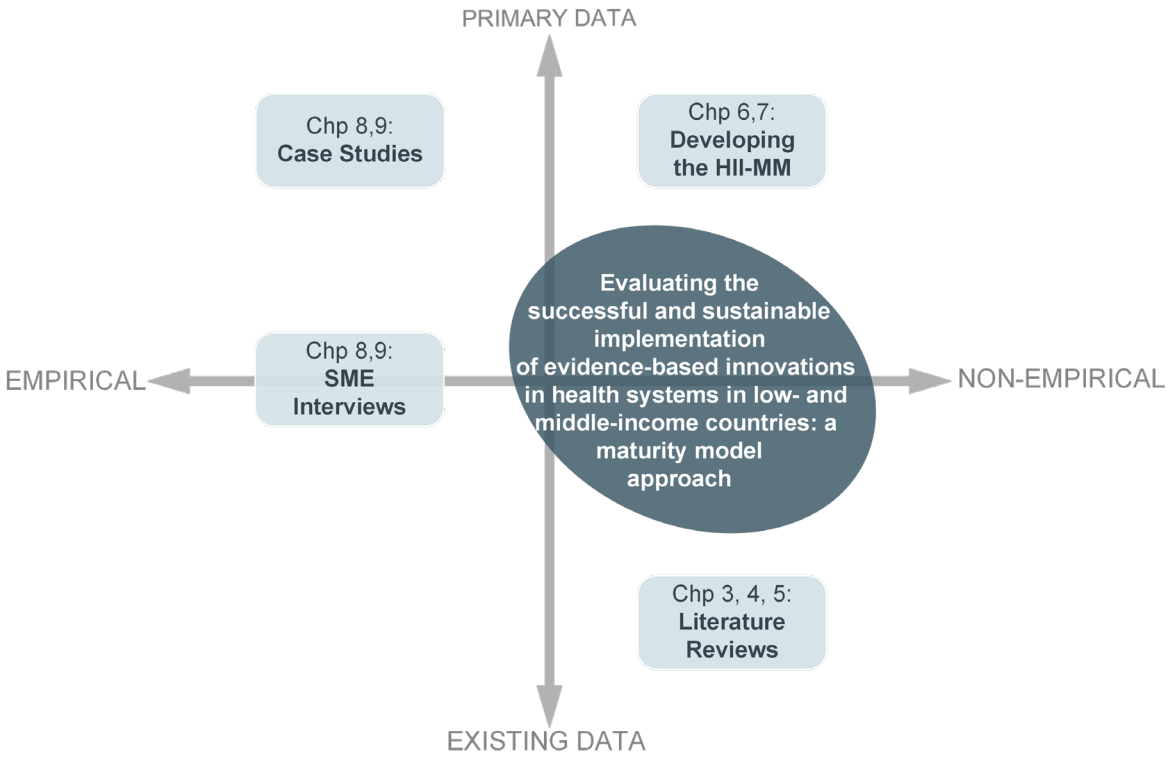

Figure 2.1: Mapping the position of this study in the research design proposed by Mouton (2001).

This study is primarily non-empirical, with some aspects of empirical research. In Chapter 3 to Chapter 5, various literature reviews are conducted (conceptual, systematic, and comparative reviews) in which existing data are interrogated to aid in developing the HII-MM. In Chapter 6 and Chapter 7, the novel HII-MM is developed and presented. In Chapter 8 and Chapter 9, the approach shifts to an empirical one, in which interviews and case studies are utilised to gain insights into the practicality, relevance, usefulness, and usability of the developed HII-MM.

2.3 RESEARCH STRATEGY

Having mapped out the scope of the study, it is necessary to identify a strategy that can be used to complete the study methodically. The strategy would need to enable the development of an assessment approach that enables a practical and holistic assessment of the facilitators and barriers to implementation present in an LMIC health innovation system, as described by research objective RO.2 (Section 1.4). The research strategy identified and subsequently utilised to achieve the aims and objectives of this study is *design science*.

Design science stems from the information systems discipline and has been used to develop novel artefacts, such as models (Johannesson and Perjons, 2014). Design science was chosen as the research strategy because its properties complement the aim of this study, which is to *develop an assessment framework that improves the number of evidence-based health innovations that are successfully and sustainably implemented in LMIC contexts*. Design science is an appropriate research strategy for this study because it can (i) describe complex systems, (ii) systematically solve a problem, and (iii) provide evidence-based solutions for real-world problems.

Design science focuses on problem solving, providing a systematic and structured approach for defining and solving a problem and developing artefacts (Baskerville, 2017; Hevner and Wickramasinghe, 2018; vom Brocke, Hevner and Maedche, 2020). The structured approach enables artefacts to be developed iteratively, which improves the artefact's scientific rigour, reliability and validity (Hevner, 2007; Holmström, Ketokivi and Hameri, 2009; Briggs and Schwabe, 2011; Venable, Pries-Heje and Baskerville, 2012). Design science's capability of developing artefacts is congruous with the study's aim of developing an assessment framework.

Design science is a "*systematic approach to defining large-scale systems*" (Jones, 2014, p.91) and is valuable for providing evidence-based solutions to complex problems (Mohrman, 2007; Hevner *et al.*, 2008). Thus, it is a useful strategy for describing the complex systems considered in this study, namely, health and innovation systems. Furthermore, design science considers the interdisciplinary nature of problems, emphasising a holistic and interdisciplinary approach to solving problems (Papalambros, 2015); this is appropriate for the study's interdisciplinary themes in which the intersection of health innovation systems, implementation capability and the LMIC context are investigated.

Utility is at the centre of design science (Winter, 2008; Venable and Baskerville, 2012); it complements theory-building approaches, placing "*additional focus on discovery and problem solving*" (Holmström, Ketokivi and Hameri, 2009, p.65) and enables practical outcomes from research that can translate into real-world impact (Miah, Kerr and Von Hellens, 2014; Baskerville *et al.*, 2018; vom Brocke, Hevner and Maedche, 2020). These design science features make it well suited to achieve the practical objectives of the study's aim of improving *the number of evidence-based health innovations that are successfully and sustainably implemented in LMIC contexts.*

Venable, Pries-Heje and Baskerville (2017) describe various existing design science strategies, which include (i) Systems Development Research Methodology, (ii) Design Science Research Process Model, (iii) Design Science Research Methodology, (iv) Action Design Research, (v) Soft Design Science Methodology, and (vi) Participatory Action Design Research. These strategies tend to have similar overarching phases, which Jones (2014) defines as: Exploratory, Formative and Evaluative Phases.

The overarching design science phases described by Jones (2014) will be used and tailored according to the study's objectives. As Table 2.1 shows, Chapter 1, Chapter 3, Chapter 4 and Chapter 5 of this study form the Exploratory Phase; Chapter 6 and Chapter 7 constitute the Formative Phase, and Chapter 8 and Chapter 9 constitute the Evaluative Phase.

Table 2.1: Design science activities, phases and corresponding chapters

	Design Science Phase (Jones, 2014)	Corresponding Chapter(s)
1	Exploratory Phase	Chapter 1, Chapter 3, Chapter 4, Chapter 5
2	Formative Phase	Chapter 6, Chapter 7
3	Evaluative Phase	Chapter 8, Chapter 9

Figure 2.2 describes the research strategy followed in the context of the overarching design science phases. During the Exploratory Phase, the specific problem and resulting objectives, as identified in Chapter 1, are investigated through three sets of literature reviews, viz., (i) conceptual,

(ii) systematic, and (iii) comparative literature reviews. During the Formative Phase, the solution to the identified problem is developed, namely the HII-MM. Lastly, during the Evaluative Phase, the developed solution, the HII-MM, is iteratively refined through content and structure verification strategies; thereafter, the efficacy of the HII-MM in solving the identified problem is validated. In the following sub-sections, the three design science phases followed to meet the aim and objectives of the study will be discussed in more detail.

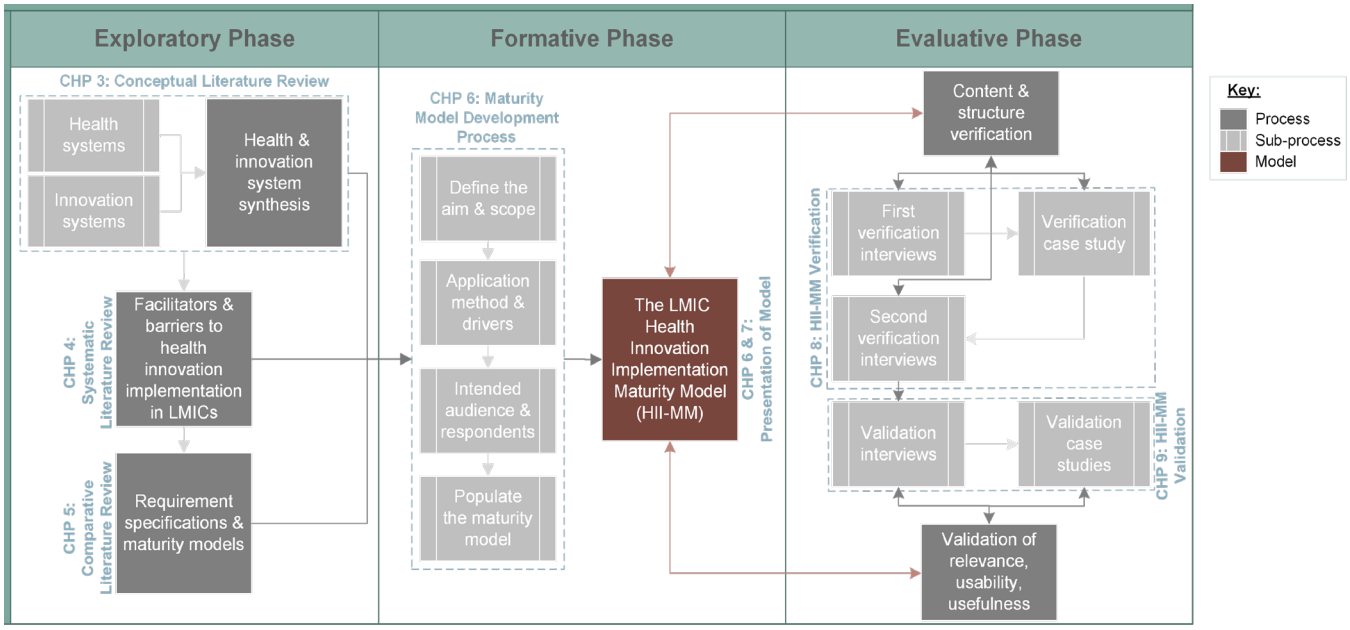

Figure 2.2: Overview of the research strategy followed for this study

2.3.1 Exploratory Phase

In response to the problem statement and objectives outlined in Chapter 1, within the Exploratory Phase of the research strategy, exploratory literature reviews were carried out using three literature techniques: (i) a conceptual literature review, (ii) a systematic literature review, and (iii) a comparative literature review. Three techniques were utilised because of the varying outcomes expected from the respective literature reviews. The conceptual literature review was used to contextualise the concepts in the problem's landscape, namely the health innovation system. The systematic literature review was used to enable a thorough understanding of the facilitators and barriers to implementing health innovations in LMICs. Lastly, the comparative literature review was used to compare existing solutions with the requirement specifications of the study to establish if any existing approach could address the problem. In the following sub-sections, overviews of the methodologies followed to complete the literature reviews are presented; the application of these methodologies is described in Chapter 3 (conceptual literature review), Chapter 4 (systematic literature review), and Chapter 5 (comparative literature review).

2.3.1.1 Conceptual Literature Review

To contextualise the problem, a conceptual literature review was carried out. The conceptual review, presented in Chapter 3, investigates the systems within which the identified problem resides – health and innovation systems.

The literature explored for this review includes innovation and health system literature. The Conceptual Framework Analysis (CFA) developed by Jabareen (2009) was utilised to guide the conceptual literature review. The CFA methodology is a qualitative approach used to develop conceptual frameworks and thus is useful for guiding conceptual literature reviews. There are numerous advantages to using the CFA methodology, including its flexibility, ability to modify the phases, and emphasis on understanding rather than predictions (Jabareen, 2009).

The CFA methodology consists of eight phases (Jabareen, 2009): (i) mapping sources, (ii) categorising data, (iii) identifying concepts, (iv) deconstructing and categorising concepts, (v) integrating concepts, (vi) synthesis, (vii) validation, and (viii) rethinking. The first six phases of the CFA were used to guide the conceptual literature review; the last two phases are not covered because the validation and rethinking phases of the study form part of the *Evaluative Phase* of the research strategy.

The conceptual literature review reviewed health systems, innovation systems and the interactions between health and innovation systems. Data on health system frameworks and innovation system approaches were mapped, categorised, and synthesised to ultimately develop a conceptual framework known as the *Conceptual Health Innovation System Framework.* The operational details of performing the conceptual literature review are described in Chapter 3, specifically on pages 26, 28, 37 and 41.

2.3.1.2 Systematic Literature Review

Having contextualised the problem, a systematic literature review, presented in Chapter 4, was used to identify the drivers of the problem. Systematic literature reviews are structured evaluations of a clearly constructed question (Moher *et al.*, 2009). The advantages of performing a systematic literature review include (Kitchenham and Charters, 2007):

i. Ensuring that the literature review is thorough;
ii. Having a defined approach for collecting studies produces results that are less likely to be biased; and
iii. Studies from various disciplines with varying methodologies can be uncovered during the review, ensuring greater accuracy and transferability of results.

The main disadvantage of performing a systematic literature review is the time and effort required to complete the review (Kitchenham and Charters, 2007). However, this outweighs the importance of conducting such a review.

The purpose of the systematic literature review in the context of this study was to: (i) gain a detailed understanding of what the facilitators and barriers to implementing health innovations in LMICs are, (ii) summarise the existing evidence present, and (iii) support the development of the HII-MM. The methodology followed was developed by consolidating the stages considered by Higgins and Green (2008) in the Cochrane handbook and by Liberati *et al.* (2009) in the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) report and consisted of the following steps:

i. Define the review: the specific literature intersection was defined to specify the scope of the review, and the inclusion criteria were defined. The review focused on the intersection between health innovations, implementation science and the LMIC context;

ii. Identify studies: studies were identified by entering pre-defined search terms into the Scopus database;
iii. Screen for eligibility: a study was deemed suitable for inclusion if it was healthcare related, specific to the LMIC context, and if it discussed the barriers or facilitators to implementation. Studies were excluded from further consideration if all of the barriers or facilitators identified in the study were deemed too case-specific or too vague to be relevant to the general LMIC context or if the study was not written in English;
iv. Extract data: the eligible studies were analysed to extract the barriers and facilitators that they had identified; and
v. Interpret results: the data extracted were first deconstructed and then categorised and interpreted according to the concepts identified in the *Conceptual Health Innovation System Framework.*

The operational details of performing the systematic literature review are described in Chapter 4, specifically on pages 56 to 62.

2.3.1.3 Comparative Literature Review

Leveraging the results from the conceptual and systematic literature reviews requirement specifications were drafted to solve the identified problem. Based on these requirement specifications, maturity models were identified as an appropriate approach to achieve the study's aim of *developing an assessment approach that can evaluate health innovation systems and their capability to implement evidence-based innovations successfully and sustainably in LMICs*.

Using the premise of a health innovation system, a comparative literature review was carried out to assess a selection of existing health and innovation maturity models and compare them to the requirement specifications. These were interrogated to determine whether any of them satisfied the requirement specifications. With no existing maturity model satisfying the requirements specifications, it was concluded that a maturity model would be developed to address the problem and achieve the study objectives effectively. The operational details of performing the comparative literature review are described in Chapter 5, specifically on pages 80 to 86. The maturity model development process will be described in the next section by introducing the Formative Phase.

2.3.2 Formative Phase

Having chosen the maturity model approach, the maturity model development processes were subsequently investigated. The operational details of carrying out the maturity model development process are presented in Chapter 6, specifically on pages 88 to 96. The resulting development process followed involved consolidating the maturity model development steps proposed by De Bruin *et al.* (2005) and Maier, Moultrie and Clarkson (2012), respectively. The maturity model development process includes: (i) plan, (ii) populate, (iii) evaluate, and (iv) maintain. During the Formative Phase, the specific activities identified during (i) plan and (ii) populate, were considered. The third step of the maturity model development process, (iii) evaluate, is described in Section 2.3.3. The process followed during the Evaluative Phase is used to refine the developed model iteratively, thus influencing the formation of the final model. The developed model should be continually maintained as per step 4 of the maturity model development process (Maier, Moultrie and Clarkson, 2012); however, such continued maintenance of the model falls outside the scope of this study and will thus not be discussed further.

During the first step of the maturity model development process, viz., (i) plan, the specific activities that have to be carried out include: defining the maturity model's scope (De Bruin *et al.*, 2005; Maier, Moultrie and Clarkson, 2012) and aim (Maier, Moultrie and Clarkson, 2012), specifying the intended audience (De Bruin *et al.*, 2005; Maier, Moultrie and Clarkson, 2012), determining the application method and drivers of application (De Bruin *et al.*, 2005), deciding who the respondents of the maturity model will be (De Bruin *et al.*, 2005), and deciding on the application areas of the maturity model (De Bruin *et al.*, 2005). The requirement specifications, which had been developed during the Exploratory Phase of the study, were utilised to complete these activities.

In the second step of the maturity model development process, viz., (ii) populate, the goal is to determine what needs to be measured (De Bruin *et al.*, 2005). In this step, the maturity levels and dimensions must be defined, and the maturity model's text should be formulated (Maier, Moultrie and Clarkson, 2012). The data collected during the three literature reviews carried out during the Exploratory Phase were integrated and synthesised, enabling the population of the maturity model's structure and thus resulting in the preliminary maturity model.

This preliminary maturity model was rigorously evaluated and iteratively refined, resulting in the final HII-MM. The final HII-MM is presented in Chapter 6, and the operationalising of the final HII-MM is presented in Chapter 7. The specific evaluation process followed is described in the next section, which looks at the Evaluative Phase.

2.3.3 Evaluative Phase

Evaluation comprises two components: (i) verification, and (ii) validation. Verification describes whether something is true or correct (Cambridge English Dictionary, 2019b); in the context of this study, verification is done to ensure that the structure and content of the HII-MM are correct. Validation describes whether "*a measure of a concept really measures the concept it is intended to measure*" (Bryman and Bell, 2011, p.174); in the context of this study, validation is done to ensure that the HII-MM is relevant, useful and usable. Table 2.2 provides an overview of the evaluation objectives and outcomes and the methods used to achieve these objectives. As Table 2.2 highlights, there were two types of evaluation methods used during the Evaluative Phase, namely, semi-structured interviews and case studies.

Table 2.2: Evaluation objectives, outcomes and method

		Evaluation Objectives and Outcomes	Evaluation Method
Verification		Theoretical Verification i. The HII-MM sufficiently describe the LMIC context; ii. The HII-MM encompasses the potential enablers and barriers to implementation in LMIC health systems; iii. There are no obvious missing components in the HII-MM; and iv. There are no irrelevant components in the HII-MM; all components included are important or relevant.	Semi-structured interviews with SMEs.
		Structure verification i. Maturity model levels are an effective structure for assessing the implementation of innovations; ii. The levels of analysis approach used (micro, meso, macro) is effective at describing health systems; and iii. The structure of the HII-MM is sufficient for practical use.	Semi-structured interviews with SMEs; and case studies.
Validation		Relevance: Validation of flexibility i. The HII-MM can be applied to a wide range of evidence-based health innovations.	Semi-structured interviews with SMEs; and case studies.
		Relevance: Validation of transferability i. The HII-MM is applicable to a wide range of LMIC health systems; and ii. The HII-MM enables a holistic assessment of an LMIC health system.	Semi-structured interviews with SMEs.
		Validation of usefulness i. The HII-MM adds value to stakeholders who are involved in implementing health innovations; it can be used to: a. Benchmark innovations or implementation strategies; b. Enlighten stakeholders, informing their ability to choose an innovation, understand and identify gaps in a health system or an innovation, and understand what went wrong in an implementation process; and c. Inform change and guide improvement initiatives with regard to adapting (modifying/adjusting) an innovation, adapting an implementation strategy or adapting components of a health system.	Semi-structured interviews with SMEs; and case studies.
		Validation of usability i. The layout of the HII-MM is understandable; and ii. The HII-MM is appropriately user-friendly while maintaining an adequate level of complexity.	Semi-structured interviews with SMEs; and case studies.

Figure 2.3 describes the evaluation process followed to iteratively refine the preliminary maturity model and develop the final HII-MM. Using two different methods to evaluate the maturity model (interviews and case studies), increases credibility and reduces bias (Rhineberger, Hartmann and Van Valey, 2005).

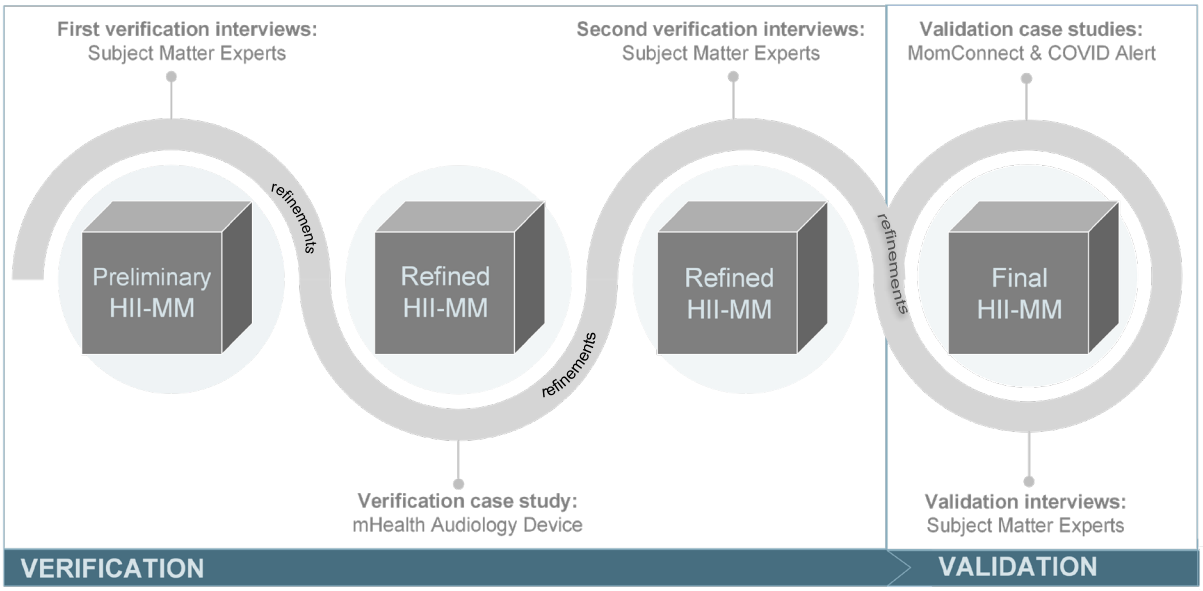

Figure 2.3: Evaluation process used to refine the HII-MM

As depicted in Figure 2.3, there were five evaluation steps followed, three of which were verification steps and two of which were validation steps; these are:

i. Performing the first verification interviews: semi-structured interviews were conducted with six subject matter experts (SMEs), to verify the theoretical and structure of the model;
ii. Performing a verification case study: once appropriate refinements had been made to the content and structure of the model, a verification case study was carried out. The objective of the verification case study was to verify the structure and practicality of the model;
iii. Performing the second verification interviews: after the verification case study, refinements were made to improve the structure and practicality of the model. Using the twice-refined model, additional semi-structured interviews were carried out with a further 27 SMEs. The purpose of the additional SME interviews was to verify the content and structure of the refined model. Relevant feedback was again incorporated into the model to produce the final HII-MM;
iv. Performing validation interviews: the 27 SMEs who had assisted with the second round of verification interviews participated in the validation interviews. These validation interviews aimed to evaluate the flexibility, transferability, usefulness and usability of the HII-MM; and
v. Performing evaluation case studies: the second part of the validation process involved conducting two case studies using the HII-MM. These case studies aimed to validate further the flexibility, usefulness and usability of the HII-MM.

The verification process is presented in Chapter 8, and the validation process is presented in Chapter 9. The methodologies followed to conduct the interviews and case studies were the same throughout the evaluation process; thus, the respective methodologies will only be described once. The interview methodology is described in Section 2.3.3.1, and the case study methodology is described in Section 2.3.3.2.

2.3.3.1 Methodology Followed for the Semi-Structured Interviews

Semi-structured interviews, as detailed in Chapter 8 and Chapter 9, were an essential part of the Evaluative Phase of the research strategy. Interviews can be an impactful part of a study; they can capture people's experiences and opinions, providing the researcher with unique perspectives (Rabionet, 2011). Rabionet, (2011) describe six steps that should be followed when conducting an interview, the interviewer should (i) decide on the interview type; (ii) set up ethical guidelines; (iii) design an interview protocol; (iv) perform the interview; (v) transcribe, summarise and analyse the interview results; and (vi) reporting the interview results. The following sub-sections discuss these steps in relation to the study.

i) Interview Type

There are three main interview types: (i) structured, (ii) semi-structured and (iii) unstructured interviews (Kajornboon, 2005). In structured interviews, the interviewer will use specific questions that he/she does not deviate from (Kajornboon, 2005). In semi-structured interviews, which are often used in qualitative studies, the interviewer will use an interview guide or guideline to ask questions that encourage the interviewee to speak more freely about certain topics or issues; this interview type is not as rigid as a structured interview (Kajornboon, 2005). Unstructured interviews do not follow a particular direction and are more casual than the previous two styles; each unstructured interview will thus be different (Kajornboon, 2005).

This study adopted the semi-structured interview style because of its greater suitability in qualitative research (Kajornboon, 2005). Semi-structured interviews provide greater flexibility, allowing the interviewer to delve deeper into certain topics as they see fit and in response to the interviewee's answers, knowledge and willingness to respond (Kajornboon, 2005).

ii) Ethical Guidelines

Having decided on the interview type (viz., semi-structured interviews) for the study, ethical guidelines were put in place, and ethical clearance was obtained. The ethical guidelines followed when conducting the interviews are in accordance with the Stellenbosch University REC. Ethical clearance was obtained from this committee (see Appendix B, Section B.1). Prior to each interview, the REC participant informed consent form was given to the interviewee; this form is presented in Appendix B, Section B.2.

iii) Interview Protocol

The basic interview protocol followed during this study consists of five overarching parts, as described in Figure 2.4. This general protocol was used for each set of interviews carried out during the study.

Figure 2.4: Semi-structured interview protocol

iv) Conducting the Interviews

The SMEs were identified through purposive sampling, a non-probability sampling technique used when expert knowledge needs to be gathered on a specific subject area (Tongco, 2007). Given the multi-disciplinary nature of this study, the SMEs selected were knowledgeable on aspects of LMIC health systems, innovation systems, maturity models, health innovations and/or implementation processes. The criteria for an SME to be included in the study included (i) relevant experience in one or more LMIC; (ii) experience with health and/or innovation systems; and (iii) knowledge of health innovation(s).

Potential interviewees were contacted via electronic mail or the online platform LinkedIn. Once an interviewee had agreed to participate in the study, relevant information was shared with him/her, including the REC informed consent form (see Appendix B, Section B.2), information on the HII-MM and the interview process (see Appendix I, Section I.4). The interviewees who participated in the validation interviews were also sent the Microsoft Excel version of the HII-MM (Appendix H). The majority of the interviews were carried out over online telecommunication platforms, such as Skype, Zoom or Microsoft Teams, with a few taking place in person (pre-2020, which marked the beginning of the COVID-19 pandemic in March 2020 and the implementation of lockdown restrictions, which prevented in-person interviews). Each interview lasted between 1 and 2 hours. The anonymised list of SMEs who participated in the interviews is presented in Appendix I, Section I.5.

v) Interview Results

Once an interview had been completed, the interview was transcribed, summarised, and analysed; the verification and validation interview results are presented in Chapter 8 and Chapter 9, respectively.

2.3.3.2 Methodology Followed for the Case Studies

Case Studies were another key tool used during the Evaluative Phase of the research strategy. A case study is an empirical tool used to investigate real-world phenomena (Yin, 2009). Having focused on non-empirical research during the Exploratory and Formative Phases of the study, case studies were an important part of the research strategy, as they demonstrated that the HII-MM was not just theoretically valid but could also be used in the context of real-world health systems.

Case studies can be intrinsic, instrumental, or collective (Stake, 1995). An intrinsic case study is used to understand a distinctive occurrence; an instrumental case study is used to gain a wider understanding of a phenomenon; and a collective case study involves numerous instrumental case studies being conducted to make an even broader conclusion about a particular phenomenon (Crowe *et al.*, 2011; Robert E. Stake, 1995). When considering each of the case studies performed in this study in isolation, they are categorised as instrumental. However, by having conducted three case studies, the group of case studies is considered as a collective, allowing for broader conclusions to be made on using the HII-MM in practice. Figure 2.5 describes the four steps followed when conducting a case study; these steps are a combination of those outlined by Tellis (1997) and Crowe *et al.* (2011).

Define the Case Study	Collect Data	Analyse & Interpret the Data	Report on the Recommendations & Conclusions
• Boundary Delimitation (scope, time frame, geographic location, and data collection techniques). • Consider the ethical implications of the case study, and obtain the relevant clearance. • Establish a case study protocol.	• Obtain informed consent from all research participants. • Collect data from a range of data sources. • Follow the protocol developed for the study.	• Transcribe the collected data. • Summarise and group the data into themes. • Analyse the results.	• When reporting on case studies, it is important to describe the following: • *The context and protocol followed; and* • *The process used to derive the case study recommendations and conclusions.*

Figure 2.5: Case study process adapted from Tellis (1997) and Crowe et al. (2011)

To identify case studies relevant to the objectives of the Evaluative Phase, innovations that had been implemented in LMIC health systems were explored. The case studies were chosen through convenience sampling, a non-probability sampling technique which reflects the cases that were accessible at a point in time (Baxter, Courage and Caine, 2015). Eligible health innovations were investigated to determine whether sufficient data were available. Thereafter, the boundaries of the case study were delineated, additional ethical clearance was obtained where necessary, and a study protocol was developed for each case study. Data were collected from a wide range of sources, including, but not limited to, interviews with relevant SMEs, surveys, academic articles, news reports, project reports, and policy documents. Prior to engaging with any research participants, their informed consent was sought. The collected data were then transcribed, summarised, analysed and interpreted to derive conclusions and recommendations. The case study results are reported in Chapter 8 and Chapter 9.

2.4 CHAPTER 2: CONCLUSION

In this chapter, the research methodology followed to achieve the aim and objectives of the study was introduced. The position of the study in the research design landscape was contemplated, and the three phases of the chosen research strategy – design science – were described. In the next chapter, the study is further conceptualised, and a conceptual literature review is conducted.

Chapter 3 Research Contextualisation: Health and Innovation Systems

In this chapter, a conceptual literature review will be carried out to identify and define the fundamental concepts that must be understood to complete this study successfully. The two types of concepts that must be understood to assess the implementation of evidence-based innovations in health systems in LMICs are the concepts present in an innovation system and those present in a health system. Before being able to assess the implementation of evidence-based health innovations, it is necessary to consider how the system in which the innovations are being implemented is structured. Thus, developing a conceptual health innovation system framework is deemed necessary. This chapter investigates health and innovation systems and the interactions between these two in a health innovation system.

There are two publications resulting from this chapter. The first publication emanates from Section 3.2, titled: *The development of a health system framework to guide the analysis of innovation adoption in low- and middle-income countries* (Leonard, De Kock and Bam, 2018). It was presented and published in the Southern African Institute for Industrial Engineering 29 conference proceedings. The second paper emanates from Section 3.4; titled: *Investigating the relationships between health and innovation systems to guide innovation adoption* (Leonard, De Kock and Bam, 2019a). It was presented and published in the 2019 IEEE International Conference on Engineering, Technology and Innovation proceedings.

Chapter 3 Outline:

3.1 CONCEPTUAL LITERATURE REVIEW METHODOLOGY

The CFA methodology developed by Jabareen (2009) and described in in Chapter 2, Section 2.3.1.1, was utilised to guide the conceptual literature review. The specific steps followed in this chapter are illustrated in Figure 3.1.

Figure 3.1: Conceptual literature review methodology followed (based on Jabareen (2009))

In Section 3.2, health systems are investigated to gain an understanding of the components and concepts present in a health system. Existing health system frameworks are mapped, and health system concepts are identified, deconstructed, categorised, and integrated. In Section 3.3, innovation systems are investigated to gain an understanding of the components and concepts present in an innovation system. Existing innovation system approaches are mapped, and innovation system concepts are identified, deconstructed, categorised, and integrated. Section 3.4 synthesises the common health system and innovation system concepts to develop the Conceptual Health Innovation System framework per research objective RO.1 of the study (see Chapter 1, Section 1.4). This framework thus contains the fundamental concepts and elements required to understand a health innovation system.

3.2 HEALTH SYSTEMS

The most commonly used definition of a health system (Hoffman *et al.*, 2012) is from the WHO's *World Health Report,* where a health system is defined as "*all the activities whose primary purpose is to promote, restore or maintain health*" (Musgrove *et al.*, 2000, p.5). This includes the resources, people, institutions and organisations whose principal aim is to improve health (World Health Organization, 2010b). In the WHO's report *Monitoring the Building Blocks of Health Systems,* the definition of a health system includes the supply of promotive, preventative, rehabilitative and curative care, by state and non-state actors (World Health Organization, 2010b).

A system consists of interconnected elements, which together form a whole; each element possesses properties of the whole (Checkland, 1981). Systems are dynamic and complex; a system outcome results from the interactions between a system's elements, not just the result of one element changing (Atun and Memable, 2008). Health systems display the significant features of complex dynamic systems (Atun and Memable, 2008). These features include (i) multiple interacting feedback loops, (ii) consequences of decisions made in a health system are often not immediately observable, (iii) a health system consists of numerous non-linear relationships, and (iv) health systems are intricately connected to their contexts (Atun and Memable, 2008).

Health systems are crucial to improving the health of a country (Atun and Memable, 2008). Health system performance correlates with the achievement of a country's health and development goals (Roberts et al., 2002). Different forms of health systems have existed since societies began to consciously protect their health and themselves from diseases (World Health Organization, 2000). Health systems, as we currently know them, have been moulded and refined from the late 19th-century health system designs (World Health Organization, 2000). Health systems are organised differently around the world, which is not to say that one way of organising a health system is better than another. What is important is that the structure of such a health system enables the good performance of the system's fundamental functions (World Health Organization, 2000).

There has been increased international interest in health systems and the frameworks that describe them (World Health Organization, 2007b). How well a health system performs correlates with the achievement of health and development goals in a country (Roberts *et al.*, 2002). Globally, institutions realise that even with health improvement initiatives focusing on particular health outcomes, more effective and efficient health systems are needed to attain and sustain health goals (World Health Organization, 2007b). The diversity of existing health system frameworks emphasises that there is no shared understanding of health systems. This can become problematic when

stakeholders interpret health systems differently and across different settings and countries (Papanicolas and Smith, 2013).

In the subsequent sub-sections, the research surrounding health system frameworks is discussed; thereafter, a consolidated health system framework is introduced, using the common concepts present in existing health system frameworks.

3.2.1 Health System Frameworks

A considerable amount of resources has been spent on developing health system frameworks (Papanicolas and Smith, 2013), leading to numerous such frameworks being published in the literature (Ergo et al., 2011). The variety of these frameworks presents challenges, as each has been developed with different driving forces in terms of emphasis, scope, usability, categories, and language (Shakarishvili et al., 2009). However, all aim to offer an enhanced understanding of health systems (Papanicolas and Smith, 2013) and provide complementary health system views (Shakarishvili et al., 2009). The various existing frameworks serve varied purposes, depending on their envisioned use and intended audience; a framework will thus emphasise certain functions or features of the health system and disregard others (Ergo et al., 2011). The complexity of health systems makes it difficult to precisely define their components (Musgrove et al., 2000).

Among international health system frameworks, there has been a substantial amount of appropriation of preceding frameworks; this suggests that some convergence in the architecture and goals of the frameworks has occurred (Papanicolas and Smith, 2013). This convergence also suggests that the value obtained from developing an entirely new framework is low (Papanicolas and Smith, 2013). Thus, a completely new health system framework will not be developed; rather, key concepts of existing health system frameworks will be integrated.

Figure 3.2 shows the specific steps of the conceptual framework methodology with regard to health systems that will be carried out in the following sections (Sections 3.2.2 to 3.2.5).

Figure 3.2: Steps followed for the conceptual literature review of health systems

In the subsequent sections, existing health system frameworks are mapped (Section 3.2.2), concepts are identified (Section 3.2.3), deconstructed and categorised (Section 3.2.4). Lastly, the identified health system concepts are integrated, and an integrated framework is presented (Section 3.2.5).

3.2.2 Health System Framework Mapping

The process followed in mapping health system frameworks is shown in Figure 3.3. The first step involved identifying existing health system frameworks; then, the identified frameworks underwent

an initial screening process, and the remaining frameworks were categorised and subsequently screened for eligibility.

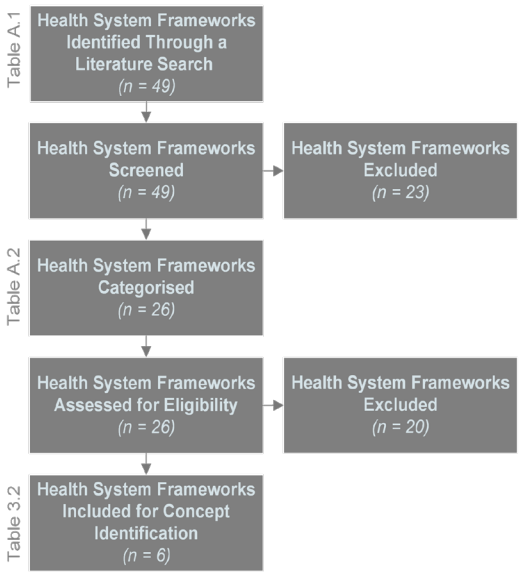

Figure 3.3: Health system framework mapping process

To determine what a health system framework should consist of, data on existing frameworks were collected by reviewing the relevant literature on Google Scholar. A snowball search method was used to identify these frameworks. The snowball method looks at a key document within a body of literature and uses the reference list and citations to identify additional documents (University Library Groningen, 2021). The document used to begin the search was the well-known Health System Building Block Framework (World Health Organization, 2007a), which has been cited over 1 500 times. From the search, 49 health system frameworks were identified, listed in Table C-1 in Appendix C. It is not claimed that this is an exhaustive list of existing health system frameworks, but it does contain the major or most influential frameworks and a large variety of health system frameworks.

As described in Figure 3.3, each of the 49 health system frameworks listed in Table C-1 was subject to an initial filtering process. For this process, the abstracts of the articles in which the frameworks were presented were screened against the following exclusion criteria:

i. The framework presents no novel elements or ideas, relying primarily on preceding frameworks;
ii. The framework was developed for a specific scenario/study and is not generalisable; and
iii. The article in which the frameworks were published is not accessible.

After applying these initial exclusion criteria, 26 health system frameworks remained; these are listed in Table C-2 in Appendix C. To ensure that the second round of filtering was more targeted, it was deemed necessary to categorise the remaining frameworks, which involved considering their boundaries and goals. The goals of a health system framework could be to:

i. Understand a health system (e.g., the system's goals, actors, functions) (Hoffman *et al.*, 2012);
ii. Illustrate and provide an overall understanding of the health system without necessarily showing how the system operates (Shakarishvili *et al.*, 2009);

iii. Compare different health systems (Hoffman *et al.*, 2012);
iv. Inform change within a health system (e.g., policy changes) (Hoffman *et al.*, 2012); or
v. Evaluate the system (Hoffman *et al.*, 2012), allowing the framework user to evaluate and analyse aspects of the health system's performance, functions and factors (Shakarishvili *et al.*, 2009), i.e., it is an interactive framework.

Another method that could be used to categorise health system frameworks is by using health system boundaries. These can be divided into three categories (Hoffman *et al.*, 2012):

i. Sub-framework: focus on specific parts of a health system (narrow boundary);
ii. Framework: encompasses the whole health system; and
iii. Supra-framework: frameworks outside the limits of traditional health systems; these frameworks consider how the health system interacts with other societal systems (wide boundary).

For this study, an amalgamation of the health system boundaries and health system goals will be used to categorise health system frameworks. By doing so, descriptive categories emerge. A visual representation of the possible categories is shown in Figure 3.4. Existing health system frameworks can be divided into these categories. For example, a framework whose goal is to inform change can be classified as a sub-framework, framework or supra-framework. Refer to Table C-2 in Appendix C for the categorisation of the health system frameworks.

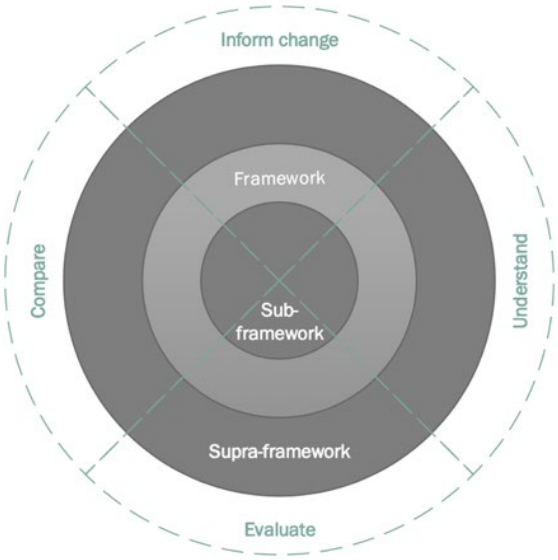

Figure 3.4: Categorisation of health system frameworks (author's representation)

Once categorised, the second set of exclusion criteria was applied to the remaining frameworks. The second set of exclusion criteria used to assess the frameworks included:

i. The exclusion of sub-frameworks: the perspectives of sub-frameworks are deemed too narrow; moreover, factors identified in these frameworks tend to be specific and do not necessarily provide a holistic or general view of a health system;
ii. The exclusion of certain supra-frameworks that are too broad or vague: all significant elements of the health system should be considered in a framework (Papanicolas and Smith, 2013);

iii. The exclusion of frameworks developed before 2000: this exclusion is justified due to the rapidly changing nature of healthcare and the absorption of preceding frameworks by more recent frameworks;
iv. The exclusion of frameworks that do not utilise a systems thinking[3] perspective: the framework should enable an understanding of health systems and how the different components identified in the system relate to and interact with one another;
v. The activities included within the health system framework's boundary must be clearly identifiable (Papanicolas and Smith, 2013); and
vi. The framework should have the ability to support the assessment of health systems in LMICs.

As described in Figure 3.3, six health system frameworks remained after the second set of exclusion criteria had been applied to the frameworks in Appendix C, Table C-2,. These frameworks are listed in Table 3.1.

Table 3.1: Health systems frameworks after the second round of filtering

Framework	Category	Reference
Health systems building block framework	Understanding framework	(World Health Organization, 2007a)
Control knobs framework	Evaluating framework	(Roberts *et al.*, 2002)
Health systems context framework	Understanding supra-framework	(Atun and Memable, 2008)
Health systems in transition	Comparing framework	(Thomson, Rechel and Ginneken, 2010)
Health systems strengthening framework	Evaluating framework	(Shakarishvili *et al.*, 2011)
Converging health systems frameworks	Understanding supra-framework	(Shakarishvili *et al.*, 2010)

Each framework in Table 3.1 offers complementary perspectives of health systems. The *health systems building blocks framework* (World Health Organization, 2007a) provides a succinct way of understanding health systems. The influence of this framework can be seen in numerous other health system frameworks. The *control knobs framework* (Roberts *et al.*, 2002) takes the approach of identifying which aspects of a health system can be influenced. The *health systems context framework* (Atun and Memable, 2008) emphasises the importance of understanding the environment in which the health system operates, as this will influence how well the health system operates. The *health systems in transition framework* (Thomson, Rechel and Ginneken, 2010) is very practical in that it offers a structured and reliable method of analysing a health system. The *health systems strengthening framework* (Shakarishvili *et al.*, 2011) provides a comprehensive list of health system elements, highlighting that all elements are interlinked. The *converging health systems framework* (Shakarishvili *et al.*, 2010) is a detailed overview of health system elements. These six frameworks are discussed in more detail in Appendix C, Section C.3.

[3] Systems thinking considers the context in which a system is operating and the system itself as a complex entity of interdependent and interconnected parts (Atun and Memable, 2008). Systems thinking is the capability to view a system as a whole and as one that contains multiple interdependent and interconnected parts, not just the individual components (Sterman, 2001).

3.2.3 Health System Concept Identification

To consolidate the six identified health system frameworks, the recurring concepts present in the frameworks need to be determined. These recurring concepts found when analysing the frameworks are: (i) context, (ii) functions, (iii) components, and (iv) goals and objectives; each of these concepts was present in two or more of the frameworks. Certain frameworks only include one of these concepts, while others include multiple; some of the frameworks would refer to the concepts using varying names. It is thus deemed necessary to define each of these concepts in turn:

i. Context refers to the circumstances that structure the background in which the health system exists and the conditions by which the health system can be understood entirely (Oxford Dictionaries, 2019a);
ii. A component can be described as a "*part or element of a larger whole*" (Oxford Dictionaries, 2018, p.1); the structure of a health system contains various components;
iii. Functions are properties that emerge as a result of the activities and interactions between components (Markard and Truffer, 2008); and
iv. Goals are general, overarching, qualitative aims; objectives are more specific and narrower in scope (Macleod, 2012).

3.2.4 Health System Concept Deconstruction and Categorisation

The six frameworks identified from the data mapping phase were analysed and deconstructed into their basic elements to determine the elements that the five health system concepts should comprise. These were then categorised according to the health system concept definitions. The categorised elements of each framework are presented in Appendix C, Section C.4. To integrate these elements, the definitions of each element (if given in the health system framework articles) were investigated to determine which elements could be consolidated due to similar and/or overlapping meanings. Once the commonalities between the various elements were found, a single term was decided upon; the consolidated elements are presented in Table 3.2. Furthermore, the description of each element and in which framework the element was specified are shown in Table 3.2.

Table 3.2: Consolidated health system elements

	Element	Description	Framework(s) in which element is specified
Context	Economic	A country's economic state affects its health system (Thomson, Rechel and Ginneken, 2010); its economy is measured by the creation and utilisation of goods and services (Oxford Dictionaries, 2019b). The economic state is influenced by the unemployment rate, the formal and informal employment mix, and by wealth distribution (Thomson, Rechel and Ginneken, 2010).	Atun and Memable (2008); Thomson, Rechel and Ginneken (2010)
	Political	The governance reflects the political state of a country. Aspects that influence the political state include the (i) area where power is centralised, (ii) the amount of influence the varying government departments and interest groups have, (iii) the major political parties present and their power, (iv) the predominant political ideologies, and (v) membership of international treaties and organisations, among other political indicators (Thomson, Rechel and Ginneken, 2010).	Atun and Memable (2008); Thomson, Rechel and Ginneken (2010)
	Socio-demographic	Socio-demographics cover the structure and characteristics of a population; the factors that affect health include education, age, language, family structure, urban or rural dwelling, religion and ethnic composition (Thomson, Rechel and Ginneken, 2010).	Atun and Memable (2008); Thomson, Rechel and Ginneken (2010)
	Epidemiology	Epidemiology refers to the frequency, distribution, and reasons for the occurrence of disease (The BMJ, 2019).	Atun and Memable (2008); Thomson, Rechel and Ginneken (2010)
	Geographic	Geography describes the climate of an area, its terrain, and its adjacent countries, as well as other physical features of an area (Thomson, Rechel and Ginneken, 2010).	Atun and Memable (2008); Thomson, Rechel and Ginneken (2010)
Functions	Service delivery	Service delivery consists of health services provided by a health system to prevent and treat ailments, and restore the health of members of a population (World Health Organization, 2007a).	Atun and Memable (2008); WHO (2007); Thomson, Rechel and Ginneken (2010); Shakarishvili *et al.* (2010) (2011)
	Resource provision	Resource provision makes the required resources available when and where they are needed (Collins English Dictionary, 2019d). This includes the generation of physical and human resources, which could be through training programmes, mobility or investments (World Health Organization, 2000).	Shakarishvili *et al.* (2010)
	Resource allocation	Resource allocation describes how the available resources (human, physical and financial) are distributed across the health system (Atun and Memable, 2008).	Shakarishvili *et al.* (2010); Atun and Memable (2008)
	Monitoring and evaluation	Monitoring and evaluation refer to the attempts by the state to shape the behaviour of health system actors' (Roberts *et al.*, 2002). It includes devising and enforcing regulations and offering strategies for health system actors (World Health Organization, 2000).	Roberts *et al.* (2002); Shakarishvili *et al.* (2010) (2011)
	Behavioural change	Behaviour describes the things people do and how they do them (Collins English Dictionary, 2019a). Behaviour is influenced by social media, religious beliefs, and mass media campaigns, among numerous other factors (Roberts *et al.*, 2002).	Roberts *et al.* (2002); Shakarishvili *et al.* (2010)

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	Element	Description	Framework(s) in which element is specified
Components	Demand generation	Demand generation involves stimulating and creating of a want or need (Collins English Dictionary, 2019b) for medical technologies, pharmaceuticals or procedures.	Shakarishvili *et al.* (2010)
	Organisational activities	There are multiple organisations active within a health system (e.g., health financing organisations, health technology companies, pharmaceutical companies, and public and private hospitals); within these organisations, various activities are being undertaken to ensure service delivery. These activities include regulating, purchasing and communicating, among others (Atun and Memable, 2008).	Atun and Memable (2008); Roberts *et al.* (2002); Shakarishvili *et al.* (2010)
	Human resources	Human resources encompass all people involved in activities that enhance or protect the health of society (World Health Organization, 2007a). There are three categories into which human resources can be divided: (i) management, (ii) service providers, and (iii) support personnel (World Health Organization, 2007a).	WHO (2007); Thomson, Rechel and Ginneken (2010); Shakarishvili *et al.* (2010)
	Physical resources	Physical resources comprise medical technologies, pharmaceuticals, infrastructure and information technology (Thomson, Rechel and Ginneken, 2010).	WHO (2007); Thomson, Rechel and Ginneken (2010); Shakarishvili *et al.* (2010)
	Financing systems	Financing systems encompass the amount and distribution of funds spent in the health system, and the sources of such funds, e.g., private insurance, out-of-pocket payments, and government coverage (Thomson, Rechel and Ginneken, 2010).	WHO (2007); Thomson, Rechel and Ginneken (2010); Shakarishvili *et al.* (2010) (2011)
	Institutions	Institutions are the rules and laws set by those in charge to guide healthcare actors (World Health Organization, 2000). The roles of institutions are to guide and oversee the health system and to protect the population that uses and is part of the health system (World Health Organization, 2007a).	WHO (2007); Thomson, Rechel and Ginneken (2010); Shakarishvili *et al.* (2010) (2011)
	Health information	The creation and use of accurate health research and information are vital for the functioning of the health system (World Health Organization, 2007a).	WHO (2007); Shakarishvili *et al.* (2010)
Goals and objectives	Improved health	Health status is a multifaceted notion consisting of numerous indicators (Madans and Webster, 2015). The ensuing goals and objectives all contribute to the health status of a population. The World Health Organization (WHO) defines health as the "*state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*" (WHO, 1948 p.1).	WHO (2007); Atun and Memable (2008); Roberts *et al.* (2002); Shakarishvili *et al.* (2010)
	Access	Access refers to the attainability of health services; accessibility depends on which health services are offered, how much they cost, and in what locations these services are offered (Roberts *et al.*, 2002).	WHO (2007); Roberts *et al.* (2002); Shakarishvili *et al.* (2010)
	Quality	Quality can be defined as the "*degree of excellence*" (Oxford Dictionaries, 2019e, p.1), i.e., how bad or how good health services or health equipment are.	WHO (2007); Roberts *et al.* (2002); Shakarishvili *et al.* (2010)

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Element	Description	Framework(s) in which element is specified
Safety	Safety in a health system is the assurance that the services do not put any actors present in the system in danger, and that they do not cause physical or emotional harm (Collins English Dictionary, 2019e).	WHO (2007); Shakarishvili *et al.* (2010)
Efficiency	An efficient health system produces the correct products and services by means of an acceptable method at a low cost to achieve better population health (Roberts *et al.*, 2002).	Atun and Memable (2008); Roberts *et al.* (2002); WHO (2007); Shakarishvili *et al.* (2010)
Social and financial risk protection	The safeguarding of healthcare actors (including patients and providers) from social and financial risks that the actors could be exposed to when interacting with health system components.	WHO (2007); Atun and Memable (2008); Roberts *et al.* (2002); Shakarishvili *et al.* (2010)
Equity	Equity can be defined as the attribute of "*being fair or impartial*" (Oxford Dictionaries, 2019c, p.1) regarding the health services provided across a population.	Atun and Memable (2008); Shakarishvili *et al.* (2010)
Consumer Satisfaction	Health consumer satisfaction is the extent to which the consumers are content with the health services provided (Roberts *et al.*, 2002).	Atun and Memable (2008); Roberts *et al.* (2002); Shakarishvili *et al.* (2010)

3.2.5 Health System Concept Integration

As described in Figure 3.2, the process's next step is integrating the identified health system concepts. The concepts identified in Sections 3.2.3 and 3.2.4 are integrated and presented in Figure 3.5. The health system components interact with one another, resulting in the emergence of functions. The components and resulting functions of the health system are influenced by their respective contexts. The context, components and functions thus interact and, in turn, affect how successful the health system is in achieving its goals and objectives.

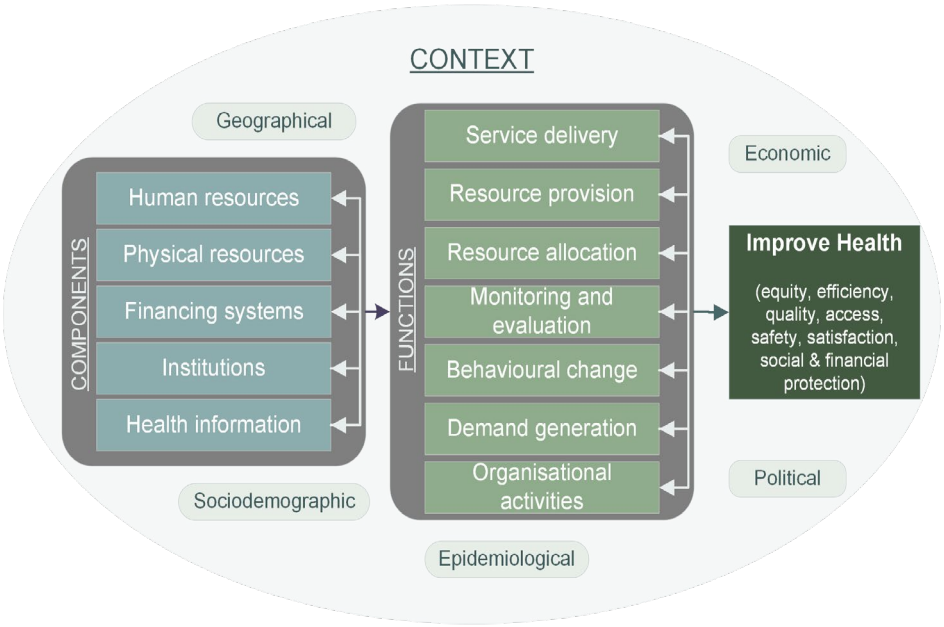

Figure 3.5: Integrated health system framework

In the next section, innovation systems are investigated. First, a general overview of innovation systems literature is given (Section 3.3.1). Thereafter, existing innovation system approaches are mapped (Section 3.3.2), concepts are identified (Section 3.3.3), deconstructed and categorised (Section 3.3.4). Lastly, the identified innovation system concepts are integrated, and an integrated innovation system framework is presented (Section 3.3.5).

3.3 INNOVATION SYSTEMS

There are numerous definitions that have been suggested for the term innovation. For the purpose of this study, the definition proposed by Katz (2007) will be used, as it consolidates key components from seven definitions of innovation. Katz (2007, p.6) describes innovation as: "*the successful generation, development and implementation of new and novel ideas, which introduce new products, processes and/or strategies to a company or enhances current products, processes and/or strategies leading to commercial success and possible market leadership and creating value for stakeholders, driving economic growth and improving standards of living*."

Innovation is frequently confused with the term "invention" (Tidd and Bessant, 2009). Invention is part of the innovation process and is the beginning stage of the innovation process (Tidd and Bessant, 2009); the aforementioned definition highlights that innovation includes the development and implementation of new ideas, not only the creation of novel ideas. Inventions do not necessarily

become innovations. Innovation can take numerous forms; Tidd and Bessant (2009) describe four categories into which an innovation can be classified. These categories are (Tidd and Bessant, 2009):

i. Product innovations: novel products or services;
ii. Process innovations: novel methods of delivering or carrying out activities;
iii. Paradigm innovations: novel ways of structuring organisations; and
iv. Position innovation: the use of products or services in new or different settings.

The innovation process is multifaceted and complicated; this is the case irrespective of the sector in which the process is being applied (Omachonu and Einspruch, 2010). To understand, describe or influence the innovation process, it is necessary to understand an innovation system's composition and dynamics (Edquist, 1997). There are varying ways in which innovation systems can be defined. However, there is a consensus among innovation scholars that the main goals of the innovation system are to develop, diffuse and utilise knowledge and innovations (Johnson, 2001; Carlsson *et al.*, 2002; Kaiser and Prange, 2004; Markard and Truffer, 2008).

The use of systems thinking when considering innovations emphasises the importance of the complex interactions, networks and linkages between stakeholders and organisations that are required for the successful development, diffusion and use of innovations (Binz and Truffer, 2017). Policymakers have started paying more attention to innovation systems due to the impact that these can have on the social and economic targets of a country (Schrempf, Kaplan and Schroeder, 2013). Since the 1990s, the innovation system concept has been gaining attention among policymakers and academia in LMICs and HICs (Dantas, 2005). International organisations, such as the Organisation for Economic Co-operation and Development (OECD) and the World Bank, have advocated the innovation system approach (Dantas, 2005).

3.3.1 Innovation System Approaches

Numerous approaches in the literature depict the systemic qualities of innovation; an innovation system can be portrayed as having numerous levels (Geels, 2004). Innovation system approaches can be used to highlight the weak points in such a system (Schrempf, Kaplan and Schroeder, 2013). The innovation system approach moves the focus away from research and knowledge production (commonly associated with the term *innovation*) towards a holistic view of the entire innovation process (Dantas, 2005). Innovation system approaches tend to complement one another (Edquist, 2001). These approaches have been developed with varying objectives and methodologies and within different fields; even so, there are numerous overlapping and corresponding features among innovation system approaches (Binz and Truffer, 2017). These are described using different spatial boundaries (Binz and Truffer, 2017); four key innovation system approaches will be discussed in Section 3.3.2.

Figure 3.6 shows the specific steps of the conceptual framework methodology that covers innovation systems; these steps will be carried out in the following sections (Sections 3.3.2 to 3.3.5).

Figure 3.6: Innovation system conceptual literature review steps followed in Section 3.3.2 to 3.3.5

In the subsequent sections, existing innovation system approaches are mapped (Section 3.3.2), and concepts are identified (Section 3.3.3), deconstructed and categorised (Section 3.3.4). Lastly, the identified innovation system concepts are integrated, and an integrated innovation system framework is presented (Section 3.3.5).

3.3.2 Innovation System Approach Mapping

The formative innovation system approach, the national innovation system (NIS), developed by Nelson (1993), Lundvall (1992) and Freeman (1987), was initially the most widely used innovation system approach (Edquist, 2001). Since then, however, other approaches have been developed, complementing the NIS (Edquist, 2001). In addition to the NIS, the regional innovation system (RIS), the sectoral innovation system (SIS) and the technological innovation system (TIS) are the most commonly used approaches (Pellegrin *et al.*, 2010; Schrempf, Kaplan and Schroeder, 2013; Botta, Mccormick and Eis, 2015; Klein and Sauer, 2016). These approaches are differentiated by their definitions of the system boundaries (Binz and Truffer, 2017). These approaches are discussed in more detail in Appendix C Section C.5.

3.3.3 Innovation System Concept Identification

The NIS, RIS and SIS approaches emphasise the components present in an innovation system. In contrast, the TIS approach focuses on the complex dynamics of the system by identifying the system's functions (Binz and Truffer, 2017). The literature search identified two concepts of an innovation system approach: components and functions. A component can be described as a "*part or element of a larger whole*" (Oxford Dictionaries, 2018, p.1). The structure of an innovation system contains components (Hekkert *et al.*, 2011). *Functions* are properties that emerge from the activities and interactions between institutions and actors (Markard and Truffer, 2008). The innovation system's functions provide insights into whether the components of the innovation system are effectively interacting to successfully develop and implement innovations (Hekkert *et al.*, 2011).

Considering only the innovation system's components, as many frameworks do, would lead to a static view of the system (Hekkert *et al.*, 2007). In comparison, the functions of an innovation system are more evaluative, which allows the performance of an innovation system to be evaluated and addressed (Hekkert *et al.*, 2011).

The various existing innovation system approaches should not be considered mutually exclusive (Archibugi, Howells and Michie, 1999); the approaches have many interrelations and similarities. The approaches complement one another (Edquist, 1997). Thus, instead of choosing a single innovation system approach, the various components and functions of the approaches will be analysed to determine a set of widely used innovation system components and functions. In the

succeeding sub-sections, the components and functions of an innovation system are described, and the conceptual consolidated innovation system framework is illustrated.

3.3.4 Innovation System Concept Deconstruction and Categorisation

The identified and selected components to describe the innovation system are largely based on NIS components. The research found that many approaches borrow or work off of the NIS components; consequently, the NIS, TIS, SIS, and RIS have many overlapping components. The five chosen components described in Table 3.3 are structured around the NIS components identified by Soete, Verspagen and ter Weel (2010). The NIS was used as the basis because the components covered in this approach are the broadest; no other innovation approach covers all of the components (this can be seen in Table 3.3). The work done by Soete, Verspagen and ter Weel (2010) was used because they reviewed an array of NIS literature through which common components are identified.

Table 3.3: Components of an innovation system

Component	Description	Innovation system where component is emphasised
Innovation	An important component that has the potential to influence the innovation system is the innovation itself. Lundvall (1992) identified the building blocks of the NIS. The first building block considers the source of the innovations; here, Lundvall (1992) differentiates between search and exploration and learning from experience, which leads to new knowledge (Soete, Verspagen and ter Weel, 2010). In the second building block, the characteristics of the innovation are considered. Here the differentiations between radical and incremental innovations are considered (Soete, Verspagen and ter Weel, 2010).	NIS (Soete, Verspagen and ter Weel, 2010) TIS (Hekkert *et al.*, 2011)
Institutions	Institutions are established as widespread laws, rules or practices that shape social interactions (Hodgson, 2006). Institutions are essential to the structure of an innovation system (Hekkert *et al.*, 2011); they offer structure and insights into how actors behave in the system (Soete, Verspagen and ter Weel, 2010). Institutions can be formal or informal and have differing scopes (Binz and Truffer, 2017). Institutions present in an innovation system include regulatory institutions, international treaties and policies, professional or other dominant cultures, technological standards, and intellectual property rights (Binz and Truffer, 2017).	NIS (Soete, Verspagen and ter Weel, 2010) RIS (Schrempf, Kaplan and Schroeder, 2013) SIS (Malerba, 2005) TIS (Hekkert *et al.*, 2011)
Knowledge	Both knowledge being introduced into the system and everyday learning are important factors in the innovation system approach (Soete, Verspagen and ter Weel, 2010). The learning process includes novel knowledge, new combinations of knowledge or the introduction of knowledge to a person or organisation that is novel to them (Soete, Verspagen and ter Weel, 2010).	NIS (Soete, Verspagen and ter Weel, 2010) RIS (Schrempf, Kaplan and Schroeder, 2013) SIS (Malerba, 2005)
Relations & networks	Innovation seldom happens in isolation. For an innovation system to be successful, continuous interaction and collaboration between actors are necessary (Soete, Verspagen and ter Weel, 2010). Interactions occur via communications, cooperation and exchanges among actors and competition (Malerba, 2005). Effective interactions generate new knowledge and allow available knowledge and innovations to be better exploited (Soete, Verspagen and ter Weel, 2010). A group of actors interacting with one another can be referred to as a	NIS (Soete, Verspagen and ter Weel, 2010) RIS (Schrempf, Kaplan and Schroeder, 2013) SIS (Malerba, 2005) TIS (Hekkert *et al.*, 2011)

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Component	Description	Innovation system where component is emphasised
	network; actors function in networks (Hekkert *et al.*, 2011). Relations & networks can be intra-organisational or extra-organisational and can be enduring, e.g., international alliances, or short-lived and topical, e.g., thematic conferences (Binz and Truffer, 2017).	
Actors	Actors include organisations (e.g., producers, universities, trade unions, R&D departments, non-governmental organisations (NGOs) and individuals (e.g., consumers) (Malerba, 2005). The actors in an innovation system create, diffuse and use the innovations (Hekkert *et al.*, 2011).	NIS (Soete, Verspagen and ter Weel, 2010) RIS (Schrempf, Kaplan and Schroeder, 2013) SIS (Malerba, 2005) TIS (Hekkert *et al.*, 2011)

Different innovation system approaches identify similar functions (Bergek, 2001). The seven identified and selected functions, described in Table 3.4, are structured around the innovation system functions identified by Hekkert et al. (2007) and Bergek (2001). Bergek (2001) analysed multiple existing innovation system approaches and identified the common innovation functions that they all shared. The innovation system functions proposed by Hekkert et al. (2007) are influenced by those identified by Bergek, given that Hekkert et al. (2007) cite Bergek (née Johnson), among other authors, in their article identifying the functions. Thus, by using the functions identified by Bergek (2001) and Hekkert et al. (2007), one can rest assured that the innovation systems have been thoroughly represented. Both Hekkert et al. (2007) and Bergek (2001) used a variety of research from the NIS and TIS literature to identify common innovation system functions; these functions; are related to one another and influence one another (Bergek, 2001).

Table 3.4: Functions of an innovation system

Function	Description
Entrepreneurial activities	Entrepreneurs include the newcomers to the innovation system who seek business opportunities, as well as the established organisations who are active in creating and using innovations in both established and new markets (Hekkert *et al.*, 2007). Active entrepreneurs' presence is vital to an innovation system's effective functioning (Hekkert *et al.*, 2007). When functioning effectively, entrepreneurial activities flourish (Hekkert *et al.*, 2007). Activities within an organisation, which have the potential to affect the innovation system, include the culture within the organisation, the presence and influence of certain individuals (e.g., project champion, networker (Essmann and Du Preez, 2009)), communication channels, policies and routines (Tidd and Bessant, 2009).
Knowledge development	Knowledge development and research and development (R&D) are fundamental to an innovation system; the functions included in knowledge development are learning by doing and searching (Hekkert *et al.*, 2007). Knowledge development can be tracked via patents, R&D investments and R&D projects (Hekkert *et al.*, 2007).
Knowledge exchange	Facilitating knowledge and information exchange is a significant function, enabling the diffusion of innovations and feedback between the system's goals and its performance (Bergek, 2001). Knowledge exchange can occur by (i) coordinating departments in an organisation, (ii) promoting cooperation among actors (Bergek, 2001), (iii) engaging in conferences or workshops, and (iv) forming or joining networks (Hekkert *et al.*, 2007).
Guidance of search	Guiding the search direction influences how actors utilise their resources (Bergek, 2001). Guidance activities within the innovation system enable problem identification, solution identification and incentives to engage with innovations and innovative work (Bergek, 2001).
Market formation	The market formation function includes stimulating and creating markets (Bergek, 2001).
Resource mobilisation	The role of the resource mobilisation function is to supply and allocate resources within the innovation system. These include human and financial resources (Hekkert *et al.*, 2007).

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Function	Description
Creation of legitimacy	It is necessary to reduce uncertainty and counteract the resistance to change to create legitimacy for an innovation. This can be done by providing information, creating enthusiasm, stimulating relations between actors, ensuring comprehensible legislatures and giving political support (Bergek, 2001).

3.3.5 Innovation System Concept Integration

As depicted in Figure 3.6, the process's next step is integrating the identified innovation system concepts. The concepts and elements identified in Sections 3.3.3 and 3.3.4 are integrated and presented in Figure 3.7.

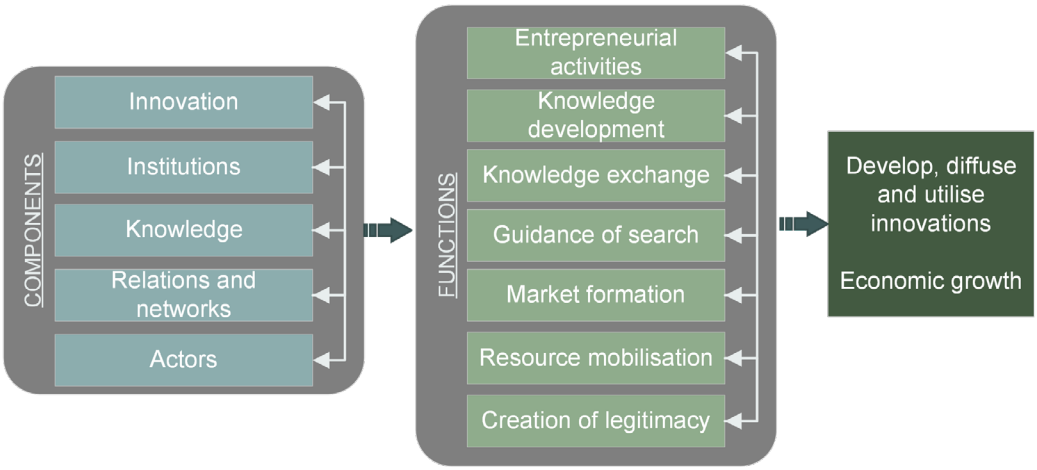


Figure 3.7: Integrated innovation system framework

As shown in Figure 3.7, the components of the innovation system interact with one another, resulting in functions emerging. These components and functions interact within their surroundings and, in turn, affect how successful the innovation system is at achieving its goals. The main goals of the innovation system are to develop, diffuse and utilise knowledge and innovations (Johnson, 2001; Carlsson *et al.*, 2002; Kaiser and Prange, 2004; Markard and Truffer, 2008). Another goal is stimulating economic growth (Organisation for Economic Co-operation and Development, 1997; Edler and Fagerberg, 2017).

In the next section, the concepts identified in health system frameworks (Section 3.2) and innovation system approaches (Section 3.3) will be synthesised to develop a conceptual health innovation system framework.

3.4 HEALTH INNOVATION SYSTEM SYNTHESIS

Figure 3.8 shows the specific step of the conceptual framework methodology that will be covered in Section 3.4. In this section, the health system concepts identified in Section 3.2 and the innovation system concepts identified in Section 3.3 are compared, with the aim of synthesising the respective concepts and developing a conceptual health innovation system framework.

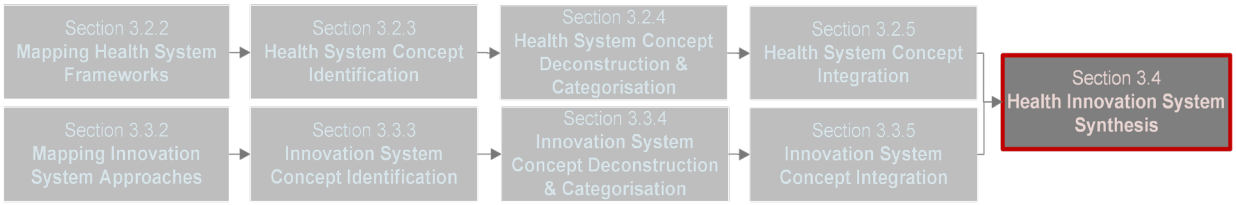


Figure 3.8: Innovation system conceptual literature review steps followed in Section 3.3.2

Innovation system theory has seldom been applied to the health sector (Morel *et al.*, 2005), even though this approach is a useful analytical tool that promotes a greater understanding of the processes involved in developing and implementing innovations (Edquist, 1997). By integrating an innovation systems approach and a health systems view, an interdisciplinary approach is emphasised, and a greater understanding of, and a distinct perspective on the relationships that enable innovation implementation are uncovered. In the innovation system literature, the focus is on developing approaches for understanding the system; in contrast, in the health system literature there is an emphasis on creating health system frameworks that show the system's structure. Even so, overlapping concepts exist in both literature fields, namely, functions, components and goals, as shown in the integrated health system framework (Figure 3.5 in Section 3.2.5) and the integrated innovation health system framework (Figure 3.7 in Section 3.3.5). In the following sub-sections, the specific concepts within each overarching concepts (components, functions, goals) will be interrogated and synthesised to develop the Conceptual Health Innovation System framework.

3.4.1 Concept Synthesis: Components

Figure 3.9 shows the concept synthesis process followed in this section. Within both the integrated health and innovation systems, specific components were identified. These components are interrogated to establish similarities and, where appropriate, are merged. This is done to develop a set of synthesised health innovation system components.

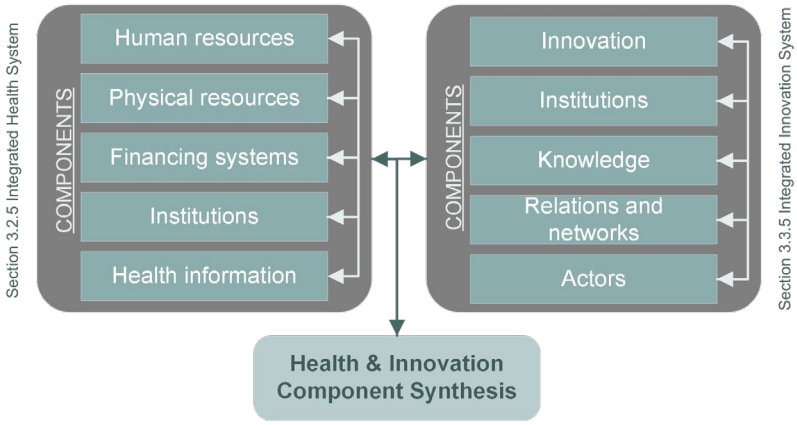


Figure 3.9: Concept synthesis – health and innovation system components

The component-centred approach enables users to identify the presence and the quality of the system's components (Grobbelaar, Gwynne-Evans and Brent, 2016). The synthesised health innovation system components are described in Sections 3.4.1.1 to 3.4.1.6. The resulting health innovation system components, which will be discussed in more detail, are *innovation* (Section 3.4.1.1), *institutions* (Section 3.4.1.2), *knowledge* (Section 3.4.1.3), *relations & networks* (Section 3.4.1.4), *actors* (Section 3.4.1.5) and *resources* (Section 3.4.1.6).

3.4.1.1 Innovation

As shown in Figure 3.10, the innovation component of the health innovation system is derived solely from the integrated innovation system framework (Section 3.3.5), as there is no component in the integrated health system framework (Section 3.2.5) that speaks to the concept of innovation. Omachonu and Einspruch (2010, p.5) define healthcare innovation as the "*introduction of a new concept, idea, service, process, or product aimed at improving treatment, diagnosis, education, outreach, prevention and research, and with the long-term goals of improving quality, safety, outcomes, efficiency and costs*". Health innovations include devices, drugs, vaccines and diagnostics (Gardner, Acharya and Yach, 2007). Conventionally, the source of health innovations was from HICs; however, LMICs are increasingly creating health innovations, too (Piot, 2012).

Figure 3.10: Innovation component

Certain characteristics of the innovation will determine its success in the health innovation system. The innovation source influences how the innovation is perceived (Damschroder *et al.*, 2009). The source of the innovation could be from search and exploration or from learning from experience (Lundvall, 1992). The quality and strength of the evidence surrounding the innovation will affect the innovation's success (Damschroder *et al.*, 2009). How compatible an innovation is with existing systems (Tidd and Bessant, 2009) and the degree to which an innovation can be adapted in different scenarios to meet varying needs affects its success (Damschroder *et al.*, 2009). An innovation's perceived complexity and cost will further influence its success (Damschroder *et al.*, 2009). Lastly, how the innovation is presented (Damschroder *et al.*, 2009) and the type of innovation it is (i.e., incremental vs radical) (Lundvall, 1992) will also contribute towards and affect its success.

3.4.1.2 Institutions

As shown in Figure 3.11, the institutions component of the health innovation system is derived from the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5). Institutions are established as widespread laws, rules or practices that shape social interactions (Hodgson, 2006); they offer structure and insights into how actors behave in the system (Soete, Verspagen and ter Weel, 2010). The roles of institutions are to guide and oversee the health system and to protect the population who use and who are part of the health system (World Health Organization, 2007a).

Figure 3.11: Institutions component

The institutional context in multiple LMICs consists of ineffective regulations and policies, weak linkages between sectors (Papaioannou *et al.*, 2015) and limited capacity (Chataway *et al.*, 2009). Institutions are further strained due to opposing interests and values in the public and private healthcare sectors (Papaioannou *et al.*, 2015). Various policies are being trialled to encourage the development of health innovations; these include liability protection, tax breaks and accelerated

regulatory approval (Gardner, Acharya and Yach, 2007). Regulation is vital in the delivery of quality healthcare services and products (Chataway *et al.*, 2009). Healthcare institutions further consist of intellectual property management, regulatory systems (including drug and vaccine regulation), international trade systems (Mahoney and Morel, 2006), national policies, international trade, and property agreements (Chataway *et al.*, 2009).

3.4.1.3 Knowledge

As shown in Figure 3.12, the health innovation system's knowledge component is derived from the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5). Knowledge can be defined as the "*information and understanding*" of a subject area (Collins English Dictionary, 2019c, p.1); thus, the health information component from the health system has been combined with the knowledge component from the innovation system.

Figure 3.12: Knowledge component

In the knowledge component, aspects that influence knowledge introduction and everyday learning in the health system are considered, including the creation and use of accurate health research and information. The degree to which LMICs take on healthcare innovations varies, with some countries having greater scientific capacity than others; this capacity results from investments in research and manufacturing infrastructure and education systems (Morel *et al.*, 2005).

In order to measure scientific capacity and R&D competencies in a country, Chataway *et al.* (2009) proposed several capabilities. These include the number of engineers and scientists present in a system, the number of journal articles and patents produced, the proportion of the gross national product spent on R&D, and the number of research organisations and universities per million people (Chataway *et al.*, 2009). Knowledge and learning are encouraged and enhanced via capacity building, interactions, and networks (Chataway *et al.*, 2009), which is the next component.

3.4.1.4 Relations & Networks

As shown in Figure 3.13, the relations & networks component of the health innovation system is derived solely from the integrated innovation system framework (Section 3.3.5). There is no component in the integrated health system framework (Section 3.2.5) that speaks to the component of relations & networks. Innovation occurs due to dynamic interactions and relations between actors (Chataway *et al.*, 2009). Health innovation networks and relations can link groups of actors at national, regional or international levels (Chataway *et al.*, 2009). Actors at all levels in the health system stand to benefit from health system relations & networks (Chataway *et al.*, 2009).

Figure 3.13: Relations & network component

Numerous existing health system networks focus on specific technologies, diseases or components of the system (Morel *et al.*, 2005). Effective networks between various health innovation actors,

including between industry, universities and research councils (Gardner, Acharya and Yach, 2007), are vital for the successful functioning of the health innovation system. Various types of partnerships and coalitions occur in the healthcare sector, including between public and private actors, local and international actors, between multi-sectoral organisations, and between industry or product-specific organisations. An example of a coalition is the International Federation of Pharmaceutical Manufacturers and Associations (Papaioannou *et al.*, 2015). Partnerships and coalitions can pressurise and influence institutions, create platforms to enable knowledge diffusion (Papaioannou *et al.*, 2015), promote learning, and foster local innovations (Morel *et al.*, 2005).

The directions of relations and interactions vary. Downstream engagement considers the diffusion of innovations into the health innovation system, while upstream engagement involves engaging with regulatory bodies to influence regulations and policies (Papaioannou *et al.*, 2015). International interactions can be classified as South-South (networks between developing or LMICs), South-North (networks between HICs and LMICs), or North-North interactions (networks between HICs). Relations & networks can be intra-organisational or inter-organisational and can be enduring, e.g., international alliances, or short-lived and topical, e.g., thematic conferences (Binz and Truffer, 2017).

3.4.1.5 Actors

As shown in Figure 3.14, the actors component of the health innovation system is derived from the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5). The actor component is present in varying degrees in the health and innovation systems. The health system has two components: (i) human resources, and (ii) financial systems, which fall under the general actor component in the innovation system. The innovation system has actors as a component. This combination of the health and innovation system components is shown in Figure 3.14.

Figure 3.14: Actors component

There is a large diversity of healthcare actors with various interests and varying influences on the healthcare landscape (Bessant, Kunne and Möslein, 2012). Bessant et al. (2012) identified five types of healthcare actors, which are displayed in Figure 3.15: (i) patients, (ii) providers, (iii) payers, (iv) suppliers and (v) regulators.

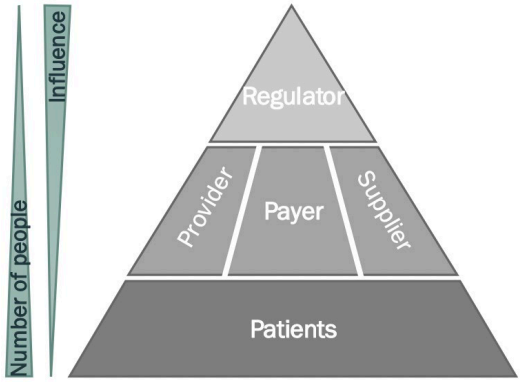


Figure 3.15: Types of stakeholders in the healthcare landscape adapted from Bessant, Kunne and Möslein (2012)

As shown in Figure 3.15, patients are the largest actor group but have the least influence; the regulator group has fewer actors but the most significant influence. In Table 3.5, the five healthcare actor groups presented in Figure 3.15 are described, and the players within each actor group are listed.

Table 3.5: Description of health innovation actor groups

Actor group	Players within group
Regulator This actor group includes groups (mainly government institutions) that assign or apply regulatory authority across healthcare landscapes (Evans, 1983). This group is responsible for regulating healthcare finances, acquisition and provision (Cassels, 1995).	i. Departments of Health, Trade and Industry, Science and Technology (Papanicolas and Smith, 2013); ii. Regional governmental health authorities (Thomson, Rechel and Ginneken, 2010); iii. Public agencies or committees at regional and national levels (Thomson, Rechel and Ginneken, 2010; Bessant, Kunne and Möslein, 2012); iv. Private sector associations (Thomson, Rechel and Ginneken, 2010); v. Consumer and patient groups (Thomson, Rechel and Ginneken, 2010); vi. Health provider and health professional associations (Thomson, Rechel and Ginneken, 2010); and vii. Trade unions.
Provider Health providers can be defined as any person or organisation involved with activities that have primarily aim to enhance health (Thomson, Rechel and Ginneken, 2010). Providers include health workers contracted by health consumers (Evans, 1983).	i. Medical experts, including doctors, midwives, nurses, pharmacists, dentists, dental auxiliaries, alternative medical practitioners, and social workers (Thomson, Rechel and Ginneken, 2010; Bessant, Kunne and Möslein, 2012) in the private, public, NGO and traditional healthcare sectors (Cassels, 1995); and ii. Medical organisations, including hospitals, health centres, doctors' offices, ambulatory surgery centres, and nursing homes (Burns, Danzon and Kimberly, 2002; Bessant, Kunne and Möslein, 2012).
Payer Payers are organisations or individuals who operationalise the financial aspects of the health system (Ritz, Althauser and Wilson, 2014), purchasing health services from health providers through various contractual mechanisms (Cassels, 1995).	i. Government agencies (Burns, Danzon and Kimberly, 2002; Bessant, Kunne and Möslein, 2012); ii. Employers (Burns, Danzon and Kimberly, 2002); iii. Individuals (Burns, Danzon and Kimberly, 2002); and iv. Health insurance (Cassels, 1995; Bessant, Kunne and Möslein, 2012).

Table continues on next page

Table continued from previous page

Actor group	Players within group
Supplier Suppliers produce the physical and human resources necessary for health systems to operate (Cassels, 1995).	i. Medical technology and pharmaceutical companies: at these companies, medical products and treatments are developed, and many resources are spent on R&D (Burns, Danzon and Kimberly, 2002; Bessant, Kunne and Möslein, 2012); ii. Pharmacies and other retailers who sell medical products (Bessant, Kunne and Möslein, 2012); iii. Higher education facilities, including universities, schools for public health, and medical schools (Cassels, 1995); and iv. Other suppliers could include scientific institutions (Bessant, Kunne and Möslein, 2012), foundations, and R&D departments in private companies (Cassels, 1995).
Patients Patients are the people who utilise or receive healthcare (Evans, 1983).	i. Members of the population who are beneficiaries of healthcare services.

The actors in the health innovation system create, diffuse and use the innovations (Hekkert *et al.*, 2011). Each actor group described in Table 3.5 have varying roles that they play in relation to one another (Ritz, Althauser and Wilson, 2014) and in relation to the health innovation system. Furthermore, each of the actor groups' viewpoints on the healthcare and innovation system differs, as does their level of influence (which has been emphasised in Figure 3.15).

3.4.1.6 Resources

As shown in Figure 3.16, the resources component of the health innovation system is derived from both the integrated innovation system framework (Section 3.3.5), and the integrated health system framework (Section 3.2.5). The resources component is present in varying degrees in both the health and innovation systems. The term "resources" was chosen to merge the physical, financial and human resources into a single component, as resources is a more descriptive term. The actor's component differs from the human and financial resources because the resources component refers to the availability and presence of resources. In contrast, the actors component describes the characteristics of the actor's (people or organisations) present in the system, including their motivations, values and attitudes.

Figure 3.16: Infrastructure component

Resources can be defined as the underlying "*supply of something that a country… has and can use*" (Oxford Dictionaries, 2019f, p.1). Healthcare resources include (i) medical technologies, (ii) pharmaceuticals, (iii) information technology (Thomson, Rechel and Ginneken, 2010), (iv) communication channels, (v) monetary funds (amount and distribution), (vi) roads, (vii) health facility buildings, (viii) internet connection, (ix) power supply, (x) water supply, and (xi) healthcare works (amount and distribution), among other factors that enable the health system to function.

3.4.2 Concept Synthesis: Functions

Figure 3.17 shows the concept synthesis process followed in this section. Within both the integrated health and innovation systems, specific functions were identified. These components are interrogated to establish similarities and, where appropriate, are merged; this is done to develop a set of synthesised health innovation system functions.

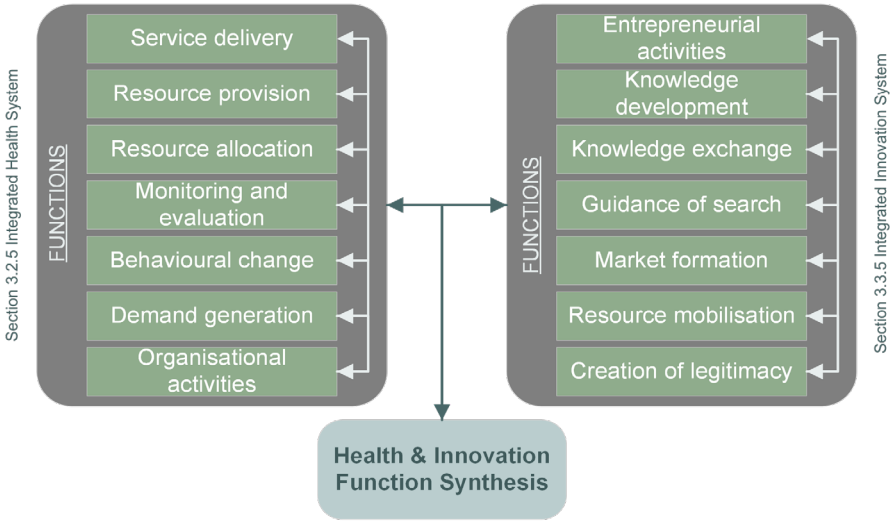


Figure 3.17: Concept synthesis – health and innovation system functions

The function-based approach can be used diagnostically, as functions describe a system at a certain point in time (Walrave and Raven, 2016); by using functions, the risk of comparing the structures of different systems is reduced (Bergek, 2001; Hekkert *et al.*, 2007). The synthesised health innovation system functions are described in Sections 3.4.2.1 to 3.4.2.8. The resulting health innovation system functions, which will be discussed in more detail, are (i) *organisational activities* (Section 3.4.2.1), (ii) *knowledge development* (Section 3.4.2.2), (iii) *knowledge exchange* (Section 3.4.2.3), (iv) *guidance of search* (Section 3.4.2.4), (v) *health service delivery* (Section 3.4.2.5), (vi) *resource mobilisation* (Section 3.4.2.6), (vii) *creation of legitimacy* (Section 3.4.2.7), and (viii) *monitoring and evaluation* (Section 3.4.2.8).

3.4.2.1 Organisational Activities

As shown in Figure 3.18, the organisational activities function of the health innovation system is derived from both the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5). Innovation systems use the term “entrepreneurial activities” to refer to organisations (both new and established) that are active in the creation and use of innovations in both established and new markets (Hekkert *et al.*, 2007). Active entrepreneurs are vital for the effective functioning of an innovation system (Hekkert *et al.*, 2007). The health system function, “organisational activities”, is a broader term that refers to the activities that occur within health system organisations; these include entrepreneurial activities.

Figure 3.18: Organisational activities function

There are multiple organisations active within a health system (e.g., health financing organisations, health technology companies, pharmaceutical companies, and public and private hospitals); within these organisations, various organisational activities are being undertaken to ensure service delivery and innovation. These activities include regulating, purchasing and communicating (Atun and Memable, 2008), as well as activities that are a result of an organisation's culture, the activities carried out by certain influential individuals (e.g., the activities of the project champion or the networker (Essmann and Du Preez, 2009)), and routines (Tidd and Bessant, 2009).

3.4.2.2 Knowledge Development

As shown in Figure 3.19, the knowledge development function of the health innovation system is derived solely from the integrated innovation system framework (Section 3.3.5), as there is no function in the integrated health system framework (Section 3.2.5) that speaks to the concept of knowledge development. Knowledge development and R&D are fundamental to an innovation system (Hekkert *et al.*, 2007) and, thus, to a health innovation system.

Figure 3.19: Knowledge development function

Knowledge development in a health innovation system can be tracked via patents, R&D investments and R&D projects (Hekkert *et al.*, 2007) relating to preventative approaches, treatment or rehabilitative healthcare. The functions included in knowledge development are learning by doing and learning by searching (Hekkert *et al.*, 2007). These functions can be carried out by any health innovation actors described in Table 3.5.

3.4.2.3 Knowledge Exchange

As shown in Figure 3.20, the knowledge exchange function of the health innovation system is derived solely from the integrated innovation system framework (Section 3.3.5), as there is no function in the integrated health system framework (Section 3.2.5) that speaks to the concept of knowledge exchange. Facilitating knowledge and information exchange is a significant function, enabling the diffusion of health innovations and feedback (Bergek, 2001) within the health innovation system.

Figure 3.20: Knowledge exchange function

The interactions among all the health innovation components determine the effectiveness of knowledge exchange in the system. Knowledge exchange can occur by coordinating departments in an organisation, promoting cooperation among actors (Bergek, 2001), engaging in conferences or workshops, and forming or joining networks (Hekkert *et al.*, 2007). These activities are emphasised within the relations & networks component discussed in Section 3.4.1.4.

3.4.2.4 Guidance of Search

Guidance of search influences how health innovation actors utilise their resources (Bergek, 2001). Guidance of search includes activities that enable problem identification, solution identification and incentives to engage with health innovations and innovative work (Bergek, 2001). As shown in Figure 3.21, the guidance of search function of the health innovation system is derived solely from the integrated innovation system framework (Section 3.3.5), as there is no function in the integrated health system framework (Section 3.2.5) that speaks to the same concept.

Figure 3.21: Guidance of search function

3.4.2.5 Health Service Delivery

As shown in Figure 3.22, the health service delivery function of the health innovation system is derived from the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5). The health service delivery function merges the innovation system function "market formation" with the health system functions "demand generation" and "service delivery".

Figure 3.22: Health service delivery function

The health service delivery function includes the provision of preventative approaches, treatment or rehabilitative services (World Health Organization, 2007a). There are numerous preventative approaches, treatments and rehabilitative activities that are present within a health system, including (i) health awareness campaigns, (ii) government drives to introduce new treatments and technologies, (iii) infection prevention activities and (iv) the provision of specialised services (such as family planning, chronic disease treatment, maternal and newborn care and malaria treatment (World Health Organization, 2010a)).

Each health service delivery activity could result in the formation of markets within the health system and demand generation for certain medical products or procedures. Market formation stimulates and creates markets (Bergek, 2001). This market creation, in turn, stimulates and creates a want or a need (Collins English Dictionary, 2019b) for certain medical technologies, pharmaceuticals or procedures.

3.4.2.6 Resource Mobilisation

Resource mobilisation combines the innovation system function, *resource mobilisation,* and the health system functions (i) *resource provision* and (ii) *resource allocation*. Resource mobilisation was chosen as the umbrella term for these three functions because mobilising resources includes ensuring that the resources are available (resource provision) and allocating the resources where

they are needed in the health innovation system (resource allocation). As shown in Figure 3.23, the health innovation system's resource mobilisation function is derived from the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5).

Figure 3.23: Resource mobilisation function

The role of the resource mobilisation function is to supply and allocate resources within the innovation system. The resources include human and financial resources (Hekkert *et al.*, 2007). Resource provision is the process of making the required resources available when and where they are needed (Collins English Dictionary, 2019d). Resource provision includes the generation of physical and human resources, which could be through training programmes, moving resources around or investments (World Health Organization, 2000). Resource allocation describes how the available resources (human, physical and financial) are designated across the health system (Atun and Memable, 2008).

3.4.2.7 Creation of Legitimacy

As shown in Figure 3.24, the creation of legitimacy function of the health innovation system is derived from both the integrated innovation system framework (Section 3.3.5) and the integrated health system framework (Section 3.2.5). Creation of legitimacy is a combination of the innovation system function "creation of legitimacy" and the health system function "behavioural change".

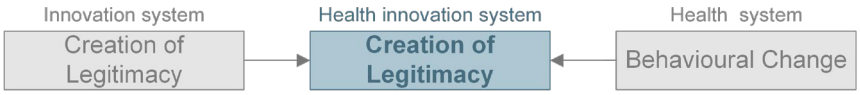


Figure 3.24: Creation of legitimacy function

Reducing uncertainty and countering the resistance to change is necessary to create legitimacy for evidence-based health innovation; this can be done by providing information, creating enthusiasm, stimulating relations between actors, and ensuring comprehensible legislatures and political support (Bergek, 2001). These actions, in turn, lead to behavioural changes within people; behaviour can be further influenced by social media, religious beliefs, and mass media campaigns, among numerous other factors (Roberts *et al.*, 2002).

3.4.2.8 Monitoring and Evaluation

Monitoring and evaluation are the attempts by actor groups (see Table 3.5) to modify the performance and conduct of health players (Roberts *et al.*, 2002). Monitoring and evaluation include devising and enforcing regulations and offering strategies for the health system actors (World Health Organization, 2000). As shown in Figure 3.25, the monitoring and evaluation function of the health innovation system is derived solely from the health system framework (Section 3.2.5), as there is no function in the integrated innovation system framework (Section 3.3.5) that speaks to the concept of monitoring and evaluation.

Figure 3.25: Monitoring and evaluation function

3.4.3 Concept Synthesis: Goals

Figure 3.26 shows the concept synthesis process followed in this section. Within both the integrated health and innovation systems, goals were identified. Contrary to the synthesis of the components and functions, each identified goal will be used in the health innovation system framework without undergoing an integration process. The goals of a health innovation system are to develop, diffuse and utilise (Johnson, 2001) health innovations, stimulate economic growth, and improve health outcomes (Morel *et al.*, 2005). Improved health outcomes can be in the form of equity, efficiency, quality, access, safety, or social and financial protection (Shakarishvili *et al.*, 2010).

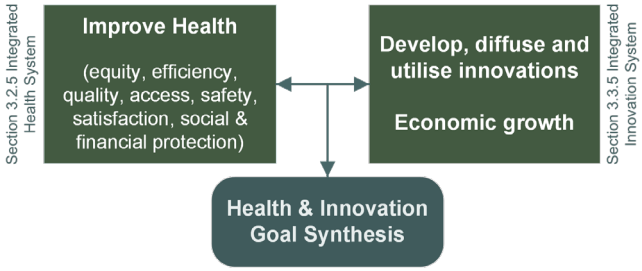


Figure 3.26: Concept synthesis – health and innovation system goals

3.4.4 Concept Synthesis: Context

The last concept considered for the health innovation system is *context*. The concepts within context are derived solely from the health system framework (Section 3.2.5), as there is no concept in the integrated innovation system framework (Section 3.3.5) that speaks to context. The resulting concepts relating to the health innovation system context are economical, geographical, political, epidemiological, and sociodemographic contexts.

It is important to understand the context in which the health innovation system operates, as it the context affects how effectively and efficiently a health system operates. A country's economic state affects its health system (Thomson, Rechel and Ginneken, 2010), and it is influenced by the unemployment rate, the formal and informal employment mix, and wealth distribution (Thomson, Rechel and Ginneken, 2010). The governance reflects the political state of a country; aspects that influence the political state include (i) the area where power is centralised, (ii) the amount of influence that varying government departments and interest groups have, (iii) the major political parties present and their power, (iv) the predominant political ideologies, and (v) membership of international treaties and organisations, among other political indicators (Thomson, Rechel and Ginneken, 2010).

Socio-demographics cover the structure and characteristics of a population. The factors that affect health include education, age, language, family structure, urban or rural dwelling, religion and ethnic composition (Thomson, Rechel and Ginneken, 2010). Epidemiology refers to the frequency of, the distribution of, and the reasons for the occurrence of disease (The BMJ, 2019). Geography describes the climate of an area, its terrain, and the adjacent countries, as well as other physical features of

an area (Thomson, Rechel and Ginneken, 2010). These contextual factors will affect how well the health innovation system performs.

3.4.5 Conceptual Health Innovation System Framework

Figure 3.27 summarises the final progression of the conceptual literature review, namely, the consolidation of the synthesised concepts developed in Sections 3.4.1 through 3.4.4. The health innovation system concepts identified in components (Section 3.4.1), functions (Section 3.4.2), goals (Section 3.4.3) and context (Section 3.4.4) are combined to generate the Conceptual Health Innovation System framework.

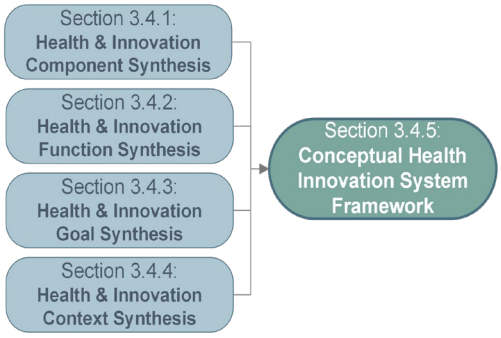


Figure 3.27: Concepts used to form the Conceptual Health Innovation System

In Figure 3.28, the *Conceptual Health Innovation System Framework* is presented. The framework includes all the concepts necessary to understand a health innovation system. The arrows in Figure 3.28 emphasise that the system's components and functions are interrelated. Functions emerge due to the activities and interactions of the components within a certain context. The functions and components interact with one another and work towards achieving the health innovation system goals. Definitions for each of the concepts identified in the *Conceptual Health Innovation System Framework* have been presented in the preceding sections. Definitions of the component concepts are presented in Section 3.4.1; function concept definitions are introduced in Section 3.4.2; goal concepts are defined in Section 3.4.3; definitions for the context concepts are described in Section 3.4.4.

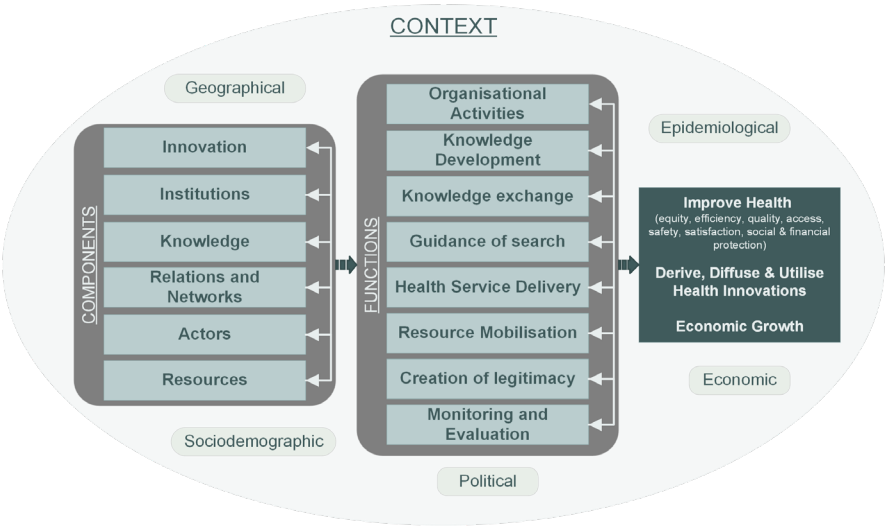


Figure 3.28: Conceptual Health Innovation System framework

The *Conceptual Health Innovation System Framework* was evaluated during the publishing process of the *Conceptual Health Innovation System Framework* in IEEE conference proceedings. The article went through a triple-blinded peer review process before being accepted for presentation at the International Conference on Engineering, Technology, and Innovation, where further engagements were had with the audience members. The framework was subsequently published in the IEEE Xplore Digital Library (Leonard, De Kock and Bam, 2019a). Furthermore, because this framework forms the foundation of the study's research product (see Chapter 6), the framework's concepts are theoretically verified during the Evaluation Phase of the research strategy (refer to Chapter 2, Section 2.3.3).

3.5 CHAPTER 3: CONCLUSION

In this chapter, a conceptual literature review was conducted. The two topics reviewed were health systems and innovation systems. The complex interactions and relationships between a system of innovation and a health system were analysed to develop the *Conceptual Health Innovation System Framework*. The framework development process uncovered clear links between the often-disconnected innovation and healthcare sectors. This framework comprises the major components present within a health innovation system. By integrating innovation and health systems, an interdisciplinary approach was emphasised, and a greater understanding of, and a distinct perspective of the relationships that enable health innovation implementation, were uncovered. The purpose of developing the Conceptual Health Innovation System framework is to describe a health innovation system.

Now that a conceptual literature review has been completed and a generic *Conceptual Health Innovation System Framework* has been defined, there is a need to link this chapter's research to an LMIC perspective. This link will be done in Chapter 4, in which a systematic literature review will be conducted to determine the facilitators and barriers to evidence-based health innovation implementation in an LMIC context. These facilitators and barriers will be categorised using the *Conceptual Health Innovation System Framework*.

Chapter 4 Health Innovation Implementation in LMICs: A Systematic Literature Review

This chapter identifies the documented facilitators and barriers to health innovation implementation in the LMIC context. First, general information on health innovation implementation in LMICs is presented; thereafter, the merits of conducting systematic literature reviews are discussed. Subsequently, a systematic literature review is conducted to address the question: *What are the facilitators and barriers to implementing health innovations in LMICs?* The systematic literature review results are integrated with the Conceptual Health Innovation System framework developed in Chapter 3. The integration is done by categorising the barriers and facilitators uncovered during the review according to the Conceptual Health Innovation System framework's concepts. One publication emulates this chapter, titled: *Barriers and facilitators to implementing evidence-based health innovations* (Leonard, De Kock and Bam, 2020a), published in the *Evaluation and Program Planning* Journal.

Chapter 4 Outline:

4.1 HEALTH INNOVATION IMPLEMENTATION IN LMICS

There has been increased attention from various health organisations (including the National Institutes of Health, the National Academy of Medicine and the WHO) on the impact of ineffective implementation of health innovations in health systems (Glasziou *et al.*, 2017; Shelton, Cooper and Stirman, 2018). In 2018 the WHO released a policy brief aimed at European countries that focuses on the implementation, sustainment and spread of healthcare innovations, emphasising the difficulties encountered during the implementation of health innovation (Nolte, 2018).

In order to understand the multifaceted implementation process of health innovations, it is necessary to investigate the facilitators that enable successful implementation (Bergström *et al.*, 2015). Furthermore, to improve the access of marginalised populations' to these innovations, it is necessary also to understand the barriers to implementation (Chopra *et al.*, 2012). Understanding the facilitators and barriers to innovation implementation is especially important in the LMIC context, where unsuccessful implementation practices impede progress in health systems (Puchalski Ritchie *et al.*, 2016). HICs and LMICs experience many of the same implementation facilitators and barriers; however, LMICs have to deal with additional health system complexities, including corruption, high disease burdens and extensive resource shortages (Vedanthan, 2011; Bergström *et al.*, 2015; Puchalski Ritchie *et al.*, 2016).

Most innovation implementation theory originates in HICs in the management information systems discipline (Abejirinde *et al.*, 2018). While there have been numerous studies conducted on health innovation implementation in the LMIC context, these studies tend to have a narrower focus area; for example, there have been studies focusing on the following:

i. The implementation context;
ii. The implementation of a specific health innovation;
iii. The behaviour of individuals involved in the implementation process; and
iv. Case studies that contemplate the constructs of the organisation implementing the innovation.

No systematic literature review was found that consolidates or summarises the facilitators and barriers to evidence-based health innovation implementation. Thus, this study is important because it fills a literature gap. In the following section, the systematic literature review methodology will be described.

4.2 SYSTEMATIC LITERATURE REVIEW METHODOLOGY

The methodology followed to conduct the systematic literature review is displayed in Figure 4.1 and is described in more detail in Chapter 2, Section 2.3.1.2. In the following sub-sections, the systematic literature review process described in Figure 4.1 is followed.

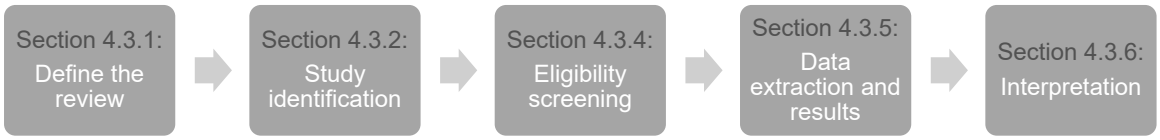


Figure 4.1: Systematic literature review process adapted from Higgins and Green (2008) and Liberati et al. (2009) with the corresponding sub-sections

4.3 PERFORMING THE SYSTEMATIC LITERATURE REVIEW

During the first stage of the systematic literature review, the specific literature intersection defines the scope, and the inclusion criteria (Section 4.3.1). Thereafter, the studies identified within the literature intersection are described (Section 4.3.2). A brief discussion of the papers published after the initial search follows in Section 4.3.3. Once identified, the studies are screened for eligibility (Section 3.4.4). The eligible studies are analysed, and the barriers and facilitators that they had identified are extracted and described in Section 4.3.5. The results extracted from the systematic literature review are discussed further in Section 4.3.6 and interpreted in the context of the broader health implementation landscape (Section 4.3.7).

4.3.1 Defining the Systematic Literature Review

This systematic literature review was conducted to identify the factors (facilitators and barriers) influencing the successful and sustainable implementation of evidence-based health innovations in LMICs. The intersection of the three themes, portrayed in Figure 4.2, is the segment of literature that will be focused on during the systematic literature review.

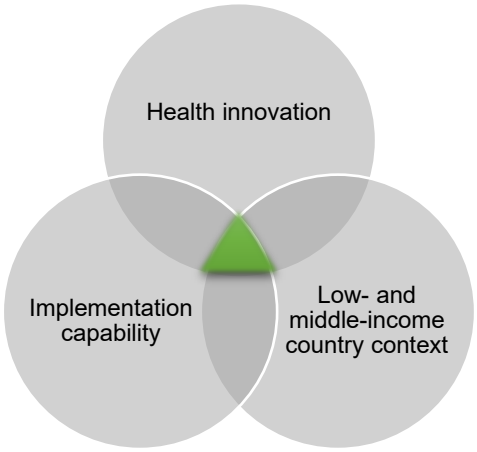


Figure 4.2: Venn diagram showing the major themes present in the systematic literature review

A study was deemed suitable for inclusion in the systematic literature review if it was healthcare related, specific to the LMIC context, and if it discussed the barriers or facilitators to implementation. Studies were excluded from further consideration if all the barriers or facilitators identified in the study were deemed too case-specific or too vague to be relevant to the general LMIC context. A preliminary search was conducted on Cochrane Library[4], Scopus[5], Google Scholar[6] and PubMed[7] to determine whether a systematic literature review had already been completed on this topic; the results of this preliminary search are displayed in Table 4.1. As shown in Table 4.1, no such review was found.

Table 4.1: Existing systematic literature reviews, preliminary search

Systematic Review Title	Description	Reference
Evidence-based guideline implementation in low- and middle-income countries: Lessons for mental health care	This article investigates the implementation of mental health clinical practice guidelines in LMICs (Docherty *et al.*, 2017). This review focuses on implementing a specific intervention, thus failing to meet the previously defined criteria of the systematic literature review.	(Docherty *et al.*, 2017)
Innovative approaches for improving maternal and newborn health - A landscape analysis	This article reviews the implementation of innovative maternal and newborn health interventions in LMICs (Lunze *et al.*, 2015). This review focuses on a particular service in the health, maternal and newborn health domain; therefore, it does not meet the previously defined criteria of the systematic literature review.	(Lunze *et al.*, 2015)
Success criteria for electronic medical record implementations in low-resource settings: A systematic review	This article investigates the criteria associated with the successful implementation of electronic medical records in low-resource settings (Fritz, Tilahun and Dugas, 2015). This review focuses on a specific innovation, viz., electronic medical records, and thus does not meet the previously defined criteria of the systematic literature review.	(Fritz, Tilahun and Dugas, 2015)
Do we have the right models for scaling up health services	This article investigates existing conceptual models that assist with the scale-up of health services (Peters *et al.*, 2011). This	(Peters *et al.*, 2011)

Table continues on next page

[4] https://www.cochranelibrary.com/
[5] www.scopus.com
[6] https://scholar.google.co.za/
[7] https://pubmed.ncbi.nlm.nih.gov/

Table continued from previous page

Systematic Review Title	Description	Reference
to achieve the millennium development goals?	review focuses on assessment models; therefore, it does not meet the previously defined criteria of the systematic literature review.	

4.3.2 Study Identification

The systematic literature review was conducted using the Scopus database. Scopus boasts the "*largest abstract and citation database of peer-reviewed literature*" (Elsevier, 2017, p.1) and contains extensive international and interdisciplinary literature from a variety of publishers and research fields (Elsevier, 2019). The interdisciplinary nature of Scopus is particularly advantageous when investigating an interdisciplinary field, such as that of implementation science. The extent of, and the peer-reviewed nature of the literature on, Scopus makes it an appropriate database to conduct a systematic literature review. The Scopus advanced search mode was utilised, and the search terms used for this review are presented in Table 4.2. The entire search strings entered into Scopus are presented in Figure D-1 and Figure D-2 in Appendix D. The search was conducted on 11 February 2019 and was not restricted by date, field or study type; however, only studies in English were investigated.

Table 4.2: Search terms used in the systematic literature review

Health **OR** healthcare	**AND**	Innovation **OR** Evidence-based Practice(s) **OR** Evidence-based intervention(s)	**AND**	Implement* **OR** Adopt* **OR** Diffus* **OR** Disseminat* **OR** Translat* **OR** Uptake **OR** Appl* **OR** Assimilat*	**AND**	Capability **OR** Readiness **OR** Maturity **OR** Ability **OR** Preparedness **OR** Factor **OR** Dimension **OR** Feature **OR** Determinant **OR** Barrier **OR** Facilitator **OR** Driver **OR** Challenge **OR** Enabler **OR** Framework **OR** Tool **OR** Model	**AND**	Low and middle income **OR** Resource constrained **OR** Resource limited **OR** Developing **OR** Sub-Saharan Africa **OR** {List of the 46 Sub-Saharan African countries}

In Scopus, the asterisk is used to return approximate matches. For example, in Table 4.2, *Implement** would return *implementation*, *implement*, *implementer*, *implemented* etc. Using the search terms from Table 4.2, the Scopus search returned 327 results. The journals in which search results were most frequently published are: (i) BMC Health Services Research, (ii) Globalization and Health, and (iii) Health Research Policy and Systems.

The publication date range of the 327 studies was between 1995 and 2019. Figure 4.3 shows that, from 2007, there was a steady increase in the number of studies published on this topic. A potential reason for the increase in publications could be the growing number of international organisations that emphasise the need to bridge the know-do gap, specifically in LMICs. In the 2004 *Ministerial Summit on Health Research* and the 2005 *World Health Assembly*, there were calls for more research in developing countries to bridge the know-do gap (Pablos-Mendez *et al.*, 2005). Furthermore, in 2011, there was a call for papers for the 2012 *World Health Report* with the theme of "*no health without research*".

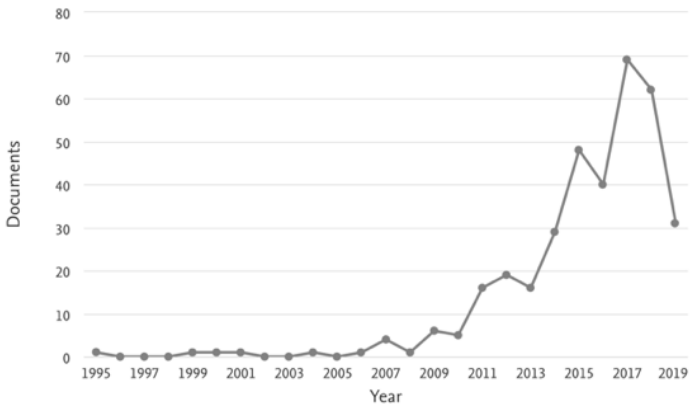


Figure 4.3: Documents published per year, primary search

VOSviewer was used to gain further descriptive insights into the resulting 327 documents. Figure 4.4 shows the network of keywords that the authors specified for their studies. These keywords are connected through co-occurrences (the number of times the keywords are used together); the size of the nodes represents how frequently the keywords occur. From the keywords, the major application areas of health implementation research in LMICs are (i) HIV, (ii) mHealth, (iii) sustainability, (iv) maternal health, (v) mental health, (vi) policy, and (vii) evidence-based practices.

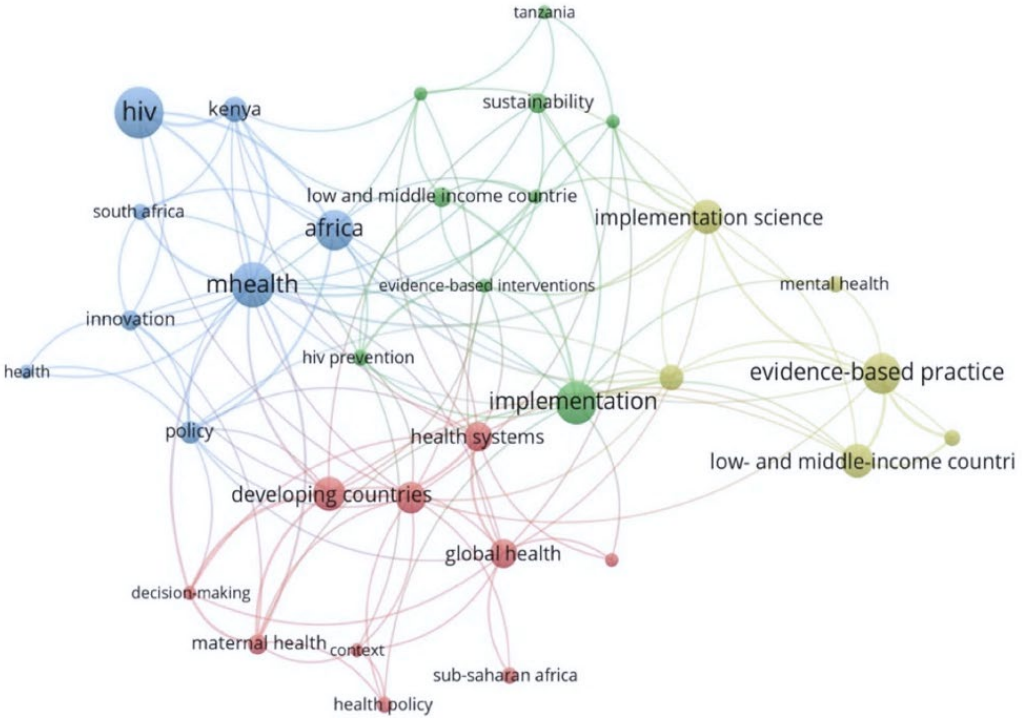


Figure 4.4: Frequency of keywords specified by authors, primary search

There is still an imbalance within this literature field, which focuses on the LMIC context, as most authors are based in HIC. Figure 4.5, drawn on VOSviewer, depicts a network of the countries where the authors of the studies are based (i.e., where the research comes from). The links between the countries represent co-authorship between countries, and the sizes of the nodes represent the number of authors present in each country. The majority of the studies come from the United States and the United Kingdom (the large green node); the third largest contributor to this research topic is South Africa, followed by Canada, Switzerland, Australia, Uganda, India, Kenya, and Sweden. This network emphasises that the bulk of the research still comes from HICs.

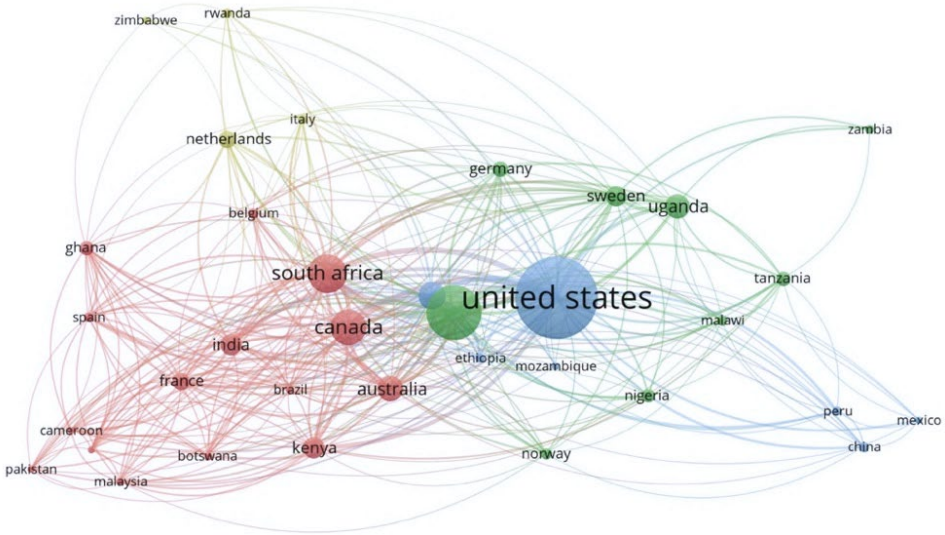


Figure 4.5: Countries where authors are based, primary search

4.3.3 Secondary Literature Search

A search was done to establish the continued relevance and uniqueness of the systematic literature review and to determine whether any other review had been done since February 2019. In addition to the four articles discussed in Table 4.1, two articles were returned. The additional articles are described in Table 4.3. The first article does not address the objectives of the proposed systematic review. The second article is published by the authors of this thesis, summarising the systematic review presented in this chapter. It is concluded that this is still a relevant review.

Table 4.3: Existing systematic literature reviews, secondary search

Systematic Review Title	Description	Reference
Sustainability of innovations in healthcare: A systematic review and conceptual framework for professional pharmacy services	This article investigates existing conceptual models and tools used to improve the sustainability of professional pharmacy services. This review focuses on models; therefore, it does not meet the previously defined criteria of the systematic literature review.	(Crespo-Gonzalez *et al.*, 2020)
Barriers and facilitators to implementing evidence-based health innovations in low- and middle-income countries: A systematic literature review	This article is the publication by the author on the work done in this chapter, Chapter 4.	(Leonard, De Kock and Bam, 2020a)

An additional search using the same search terms presented in Table 4.2 was carried out on 11 August 2021 to understand how the literature field has evolved since the preliminary systematic literature review search. An additional 233 studies were returned, indicating that the papers published in this literature field continue to trend upward, highlighting the continued relevance of this study. From the keywords, the major application areas of health implementation research in LMICs between 2019 and 2021 were: (i) HIV, (ii) evidence-based practices, (iii) mental health, (iv) digital health, (v) mHealth, (vi) COVID-19, and (vii) health policies.

In the next section, the third stage of the systematic literature review methodology will be carried out: eligibility screening (refer to Figure 4.1 for the methodology). The articles identified in the primary literature search (Section 4.3.2) are used during the eligibility screening process.

4.3.4 Screening the Studies for Eligibility

The process of identifying the eligible studies to be included in the systematic literature review is shown in the PRISMA flowchart in Figure 4.6. In addition to the 327 results identified during the primary search (Section 4.3.2), five additional articles were identified and deemed relevant for inclusion in the review. As described in Figure 4.6, the 332 studies were screened, and duplicates were removed; once duplicates had been removed, an additional screening process was followed, in which the abstracts and titles of the 316 identified studies were screened against the following exclusion criteria:

i. The study is in a language other than English;
ii. The study is not healthcare related; or
iii. The study is not specific to the LMIC context.

After this initial screening, the remaining 153 studies were downloaded, and the full papers were assessed in more detail against the following exclusion criteria:

i. The study is not specific to the LMIC or health contexts;
ii. The study does not describe any facilitators or barriers;
iii. Barriers or facilitators identified in the study are too case-specific (not transferrable); or
iv. Barriers or facilitators identified in the study are too vague to be relevant to the general LMIC context.

As shown in Figure 4.6, after the second round of screening, 79 studies were included in the next stage of the systematic literature review, namely, data extraction (Section 4.3.5). The 79 studies included in the data extraction stage and their objectives are described in Appendix D in Table D-1.

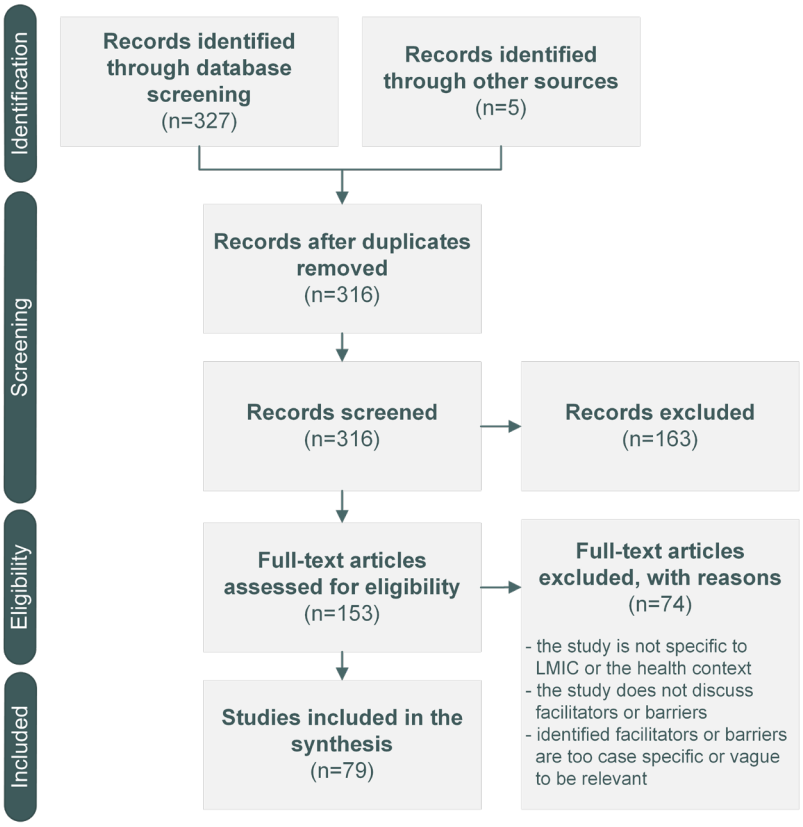


Figure 4.6: PRISMA flowchart of the systematic literature review

4.3.5 Data Extraction and Results

In the third stage of the systematic literature review methodology (Figure 4.1), data from the studies included for synthesis, as identified in Section 4.3.4, are extracted. Each of the 79 identified studies was analysed, and the barriers and facilitators to implementing health innovations in LMICs were extracted. The publication dates of the 79 studies identified for extraction (Section 4.3.4) ranged from 2004 to 2019. Figure 4.7 shows that the focus of the 79 eligible studies was on African countries and the general LMIC context.

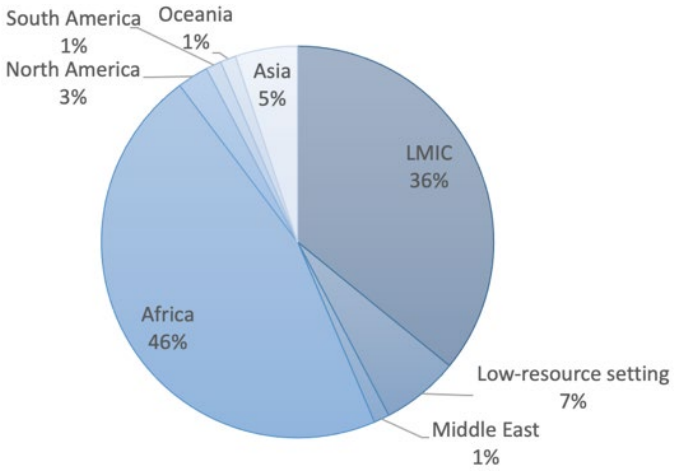


Figure 4.7: Chart showing the focus areas of the studies

The barriers and facilitators extracted from the eligible studies were analysed and categorised according to the concepts in the Conceptual Health Innovation System framework (refer to Chapter 3, Section 3.4). The concepts from the Conceptual Health Innovation System framework into which the extracted barriers and facilitators were categorised are: (i) actors, (ii) innovation, (iii) institutions, (iv) knowledge, (v) relations & networks, (vi) context, and (vii) resources. The resulting consolidated facilitators and barriers, categorised into the relevant concepts, are displayed in the cause-effect diagram in Figure 4.8. Each facilitator and barrier identified was categorised into the relevant concept; furthermore, similar facilitators and barriers were grouped accordingly. These concepts all interact with one another (to varying degrees) to determine the effectiveness and sustainability of implementing the health innovation. These implementation concepts and their sub-components will be discussed in more detail in the following sub-sections (Sections 4.3.5.1 to 4.3.5.7).

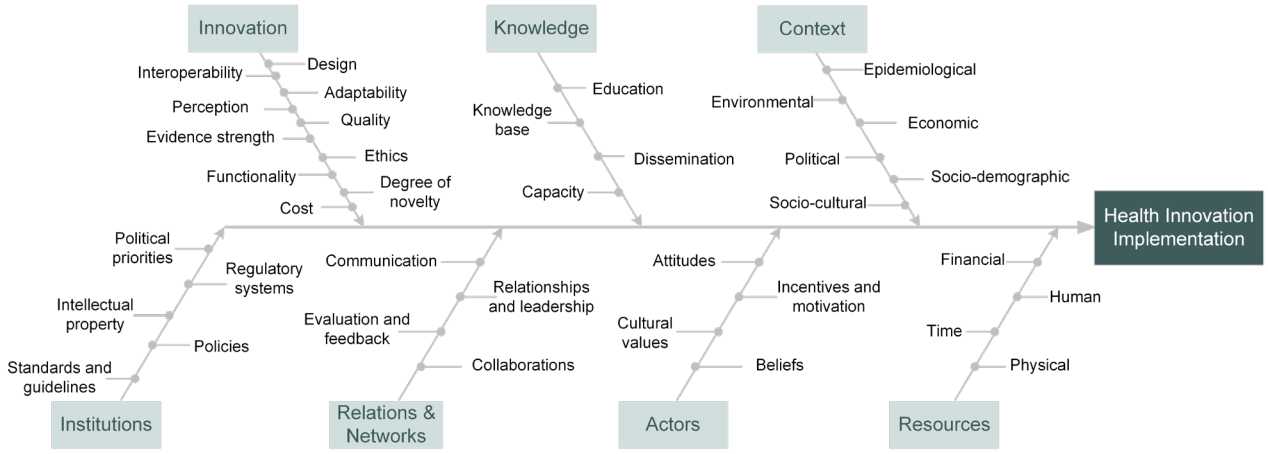


Figure 4.8: Cause-effect diagram of health innovation implementation in LMICs

4.3.5.1 Innovation

The characteristics of the health innovation, which facilitate or hinder its implementation in LMIC health systems, as extracted from the eligible studies, include: (i) its interoperability, (ii) the perceptions by stakeholders of the innovation, (iii) its cost, (iv) functionality, (v) evidence strength, (vi) adaptability, (vii) the ethics of the innovation, (viii) its quality, (ix) degree of novelty and (x) the design of the innovation. Figure 4.9 displays the frequency with which each *innovation* sub-component appeared in the eligible systematic literature review studies.

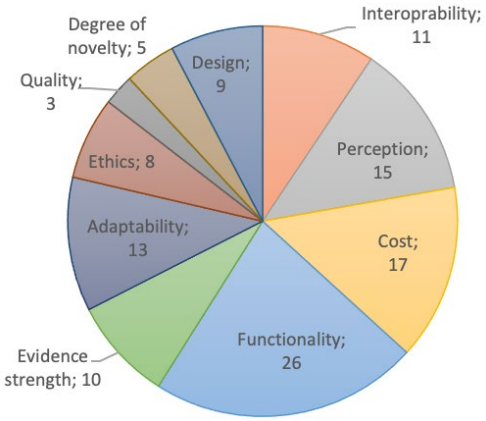


Figure 4.9: Chart showing the frequency of the innovation sub-components

The interoperability of an innovation with the system into which it is being implemented can also be described as its compatibility or as the innovation's degree of fit (Baker *et al.*, 2018; Starmann *et al.*, 2018). Innovations should not be run in silos, as silos within a system are not conducive to interoperability (Kiberu, Mars and Scott, 2017). The factors that affect an innovation's interoperability include its compatibility with the health system's existing resources and its impact on these resources (Huang, Blaschke and Lucas, 2017). Resource compatibility is linked to the innovation's specifications – these specifications should be by the conditions under which it will be used (Diaconu *et al.*, 2017). An innovation should thus be in harmony with the system in which it is being implemented (Spicer *et al.*, 2018). This alignment could be in terms of the operating temperatures, humidity, or workforce required to operate the innovation (Cunningham *et al.*, 2016); this will be discussed in more detail in the Context and Resources components.

The innovation's perceived threats, such as its complexity or the fear of adverse effects, as well as its benefits, such as the economic and health advantages of implementing the innovation, will all influence the implementation process (Graham and Mishra, 2011; Yamey, 2012; Jha *et al.*, 2016; Uzochukwu *et al.*, 2016; Diaconu *et al.*, 2017; Wainberg *et al.*, 2017; Starmann *et al.*, 2018; Young *et al.*, 2019).

The cost component is the monetary value associated with the innovation. The cost of the innovation includes the acquisition, installation, training, maintenance, and disposal costs and the costs of using the innovation (Oppong, 2015; Diaconu *et al.*, 2017).

The functionality of the innovation refers to how the innovation functions or operates. The innovation's functionality must be user-friendly and effective at delivering on its promised functions (Leon, Schneider and Daviaud, 2012; Choy *et al.*, 2013; Murray, Familiar, *et al.*, 2013; Folaranmi, 2014; Wilson *et al.*, 2014; Cunningham *et al.*, 2016; Diaconu *et al.*, 2017; Khatib *et al.*, 2017; Aamir *et al.*, 2018). An innovation is more desirable if the results and benefits from using the innovation are observable (Baker *et al.*, 2018; Starmann *et al.*, 2018). Furthermore, the innovation's functions should be needs-based, as this will ensure that it is culturally relevant and as lead to greater sustainability (Oppong, 2015; Bloom *et al.*, 2017; Kiberu, Mars and Scott, 2017).

The evidence strength supporting the innovation also affects the integrity, legitimacy and credibility of the innovation (Wilson *et al.*, 2014; L A. Palinkas *et al.*, 2015; Bardosh *et al.*, 2017; McRobie *et al.*, 2017; Aamir *et al.*, 2018; Spicer *et al.*, 2018). Thus, the strength of the evidence legitimising the innovation influences its implementation.

In the LMIC context, it is important to consider the innovation's adaptability (its ability to be modified) (Choy *et al.*, 2013; Murray, Familiar, *et al.*, 2013; Sanner, 2017; Abejirinde *et al.*, 2018; Tran Ngoc *et al.*, 2018); the environment in which the innovation is being implemented is not necessarily the environment in which it was designed to be used. Adaptability can be described as the transferability of an innovation to different environments.

The ethics of an innovation relate to the privacy and security issues associated with the innovation, as well as the risks of implementing the innovation (Graham and Mishra, 2011; Leon, Schneider and Daviaud, 2012; Folaranmi, 2014; Fritz, Tilahun and Dugas, 2015; Uzochukwu *et al.*, 2016). Ethics is a prominent and important topic, especially when discussing electronic medical records or any other innovation where patient data are being handled or stored (Folaranmi, 2014; Kiberu, Mars and Scott, 2017).

The quality of the innovation covers its durability and longevity, which considers how often maintenance and upgrades are required (Leon, Schneider and Daviaud, 2012; Spiegel *et al.*, 2012; Diaconu *et al.*, 2017).

The degree of novelty concerns the type of innovation being implemented (Abejirinde *et al.*, 2018; Baker *et al.*, 2018). Tidd and Bessant (2009) described an innovation's degree of novelty from incremental to radical. When assessing the degree of novelty of an innovation, the presence (or absence) of alternatives should be considered (Nzinga *et al.*, 2009; Abejirinde *et al.*, 2018). It is important to avoid duplicating efforts in resource-constrained LMIC health systems (Vasan *et al.*, 2015; Baker *et al.*, 2018).

Lastly, the design of the innovation influences its implementation (Ollerhead and Osrin, 2014; Uzochukwu *et al.*, 2016; Shroff *et al.*, 2017). How the innovation is presented, the language and the overall design should all be attractive and easily understandable.

4.3.5.2 Institutions

The institutional facilitators and barriers to the successful and sustainable implementation of innovations, as extracted from the eligible studies, include (i) standards and guidelines, (ii) policies, (iii) regulatory systems, (iv) intellectual property, and (v) political priorities. The chart in Figure 4.10 displays the frequency with which each *institutions* sub-component appeared in the eligible systematic literature review studies.

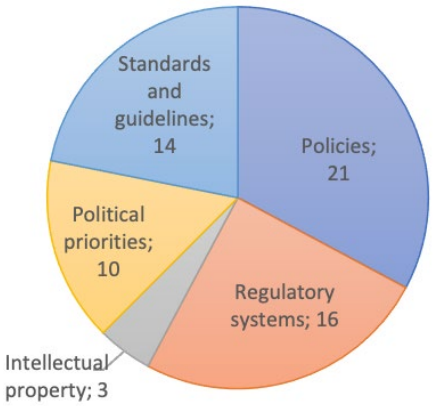


Figure 4.10: Chart showing the frequency of the institution sub-components

The policies present within the health system can be facilitators or barriers to implementing innovations (Hamel and Schrecker, 2011; Fritz, Tilahun and Dugas, 2015; Kiberu, Mars and Scott, 2017; Mijumbi-Deve and Sewankambo, 2017; Spagnolo *et al.*, 2018). There should be consistency between different policies, and policies should be aligned with the overall health goals in a country (Leon, Schneider and Daviaud, 2012; Fowkes *et al.*, 2016; Aamir *et al.*, 2018). Policies that are complex, not adequately defined, or that clash with the innovation guidelines act as barriers to implementation (Jha *et al.*, 2016; Puchalski Ritchie *et al.*, 2016; McRobie *et al.*, 2017). Furthermore, the policy environment should be supportive, enabling the implementation of evidence-based health innovations (Haines, Kuruvilla and Borchert, 2004; Peters *et al.*, 2011; Leon, Schneider and Daviaud, 2012).

Regulation includes the laws, legislations and restrictions that govern the activities within the health system. Regulatory systems affect implementation at various levels in the health system (Hamel and Schrecker, 2011; Yamey, 2012; Ollerhead and Osrin, 2014; Diaconu *et al.*, 2017; Tran Ngoc *et al.*, 2018). Numerous regulatory barriers have been identified, which include unregulated commercial interests, weak regulatory enforcement, weak regulatory mechanisms, and lack of professional regulation (Haines, Kuruvilla and Borchert, 2004; Graham and Mishra, 2011; Chopra *et al.*, 2012). To facilitate the implementation of innovations, a supportive and effective regulatory environment is necessary (Bloom *et al.*, 2017).

Intellectual property also influences innovation implementation (Spicer *et al.*, 2018). The types of intellectual property that affect the implementation of health innovations include patent monopolies, global patent protections and proprietary licensing (Graham and Mishra, 2011; Spiegel *et al.*, 2012).

The political priorities of the stakeholders involved in the implementation process can enable or hinder implementation too. Aligning the priorities of the stakeholders involved is an important enabler. Differing priorities can occur between donor organisations, international advocacy groups, treaties, within health organisations and nationally (McRobie *et al.*, 2017). Furthermore, there are competing disease priorities within the area of health priorities, e.g., between malaria and HIV (Graham and Mishra, 2011; Catalani *et al.*, 2014). Existing priorities, such as prioritising evidence use, can enable political support in implementing an innovation (Pérez-escamilla *et al.*, 2012; Braddick *et al.*, 2015; Shroff *et al.*, 2017).

Standards and guidelines include best practice guidelines, procedures to guide use, training documents and protocols. The existence and awareness of standards and guidelines directed at an innovation can affect the implementation process (Ishijima *et al.*, 2014; Braddick *et al.*, 2015; Puchalski Ritchie *et al.*, 2016; Kiberu, Mars and Scott, 2017). Inadequacies, inconsistencies and conflicts between the various standards and guidelines, as well as a lack of adherence to the guidelines, hinder implementation (Nzinga *et al.*, 2009; Fowkes *et al.*, 2016).

4.3.5.3 Knowledge

The knowledge facilitators and barriers, as extracted from the eligible studies, include (i) dissemination, (ii) knowledge base, (iii) capacity and (iv) education. Figure 4.11 displays the frequency with which each *knowledge* sub-component appeared in the eligible systematic literature review studies.

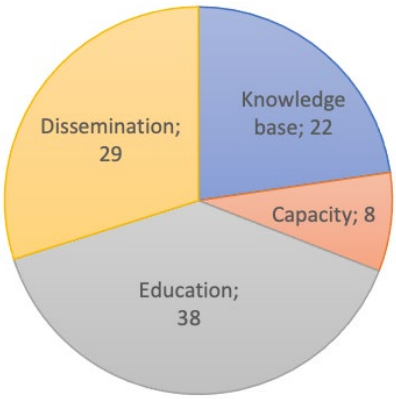


Figure 4.11: Chart showing the frequency of the knowledge sub-components

The knowledge base includes the expertise and skills present in an organisation (Puchalski Ritchie *et al.*, 2016; Huang, Blaschke and Lucas, 2017; Abejirinde *et al.*, 2018). Specific expertise and skills identified as enabling and hindering implementation include technological, research uptake and computer skills (Braddick *et al.*, 2015; Cunningham *et al.*, 2016; Uzochukwu *et al.*, 2016; Abejirinde *et al.*, 2018; Shayan, Kiwanuka and Nakaye, 2019). The low profile of implementation science and the knowledge deficit of dissemination approaches act as barriers to implementation (Yamey, 2012). Furthermore, insubstantial knowledge of the innovation hinders implementation (Aamir *et al.*, 2018).

Capacity refers to the R&D capacity. Local research production is necessary to evaluate and adapt innovations (El-Jardali *et al.*, 2014; Wainberg *et al.*, 2017). The presence of researchers and research institutions in the national health system can be facilitators of implementation (El-Jardali *et al.*, 2012).

Education includes the availability of training and health education in a country. Training can be in the form of manuals, videos, workshops, courses, simulation learning, case-based learning, or on-the-job learning (Bergström *et al.*, 2015; Cunningham *et al.*, 2016; Raney *et al.*, 2019). The medical curriculum in a country can influence implementation; outdated or inadequate curricula are hindrances (Haines, Kuruvilla and Borchert, 2004; Pérez-escamilla *et al.*, 2012; Puchalski Ritchie *et al.*, 2016; Spagnolo *et al.*, 2018). An environment that fosters learning and ongoing training is implementation facilitators (George *et al.*, 2011; Davy and Patrickson, 2012).

Dissemination encompasses the recognition of the value of knowledge and information and the awareness of the innovation (Hamel and Schrecker, 2011; Ollerhead and Osrin, 2014; van de Vijver *et al.*, 2015; Iwelunmor *et al.*, 2016; Jha *et al.*, 2016; Alto and Petrenko, 2017; Aamir *et al.*, 2018). Awareness is linked to knowledge sources and the quality and clarity of information (Aniteye and Mayhew, 2013; Puchalski Ritchie *et al.*, 2016; Mbau and Gilson, 2018). The sources of knowledge could come from an internal or an external source. Knowledge sources include the internet; participation in conferences, seminars, workshops or symposia; printed materials such as textbooks, local publications, scientific journals and clinical practice guidelines; marketing (ethically or unethically); the media; and interpersonal communication (Haines, Kuruvilla and Borchert, 2004; Chopra *et al.*, 2012; Davy and Patrickson, 2012; Pérez-escamilla *et al.*, 2012; Bergström *et al.*, 2015; Jha *et al.*, 2016; Puchalski Ritchie *et al.*, 2016; Glasziou *et al.*, 2017; Starmann *et al.*, 2018). Other factors affecting the awareness of an innovation include dissemination methods, and the availability and accessibility of international and national research (Haines, Kuruvilla and Borchert, 2004; El-Jardali *et al.*, 2012, 2014; Yamey, 2012; Puchalski Ritchie *et al.*, 2016; Shayan, Kiwanuka and Nakaye, 2019).

4.3.5.4 Relations & Networks

The facilitators and barriers of the relations & networks component, as extracted from the eligible studies, include (i) communication, (ii) collaborations, (iii) evaluation and feedback, and (iv) relationships & leadership. Figure 4.12 displays the frequency with which each *relations & networks* sub-component appeared in the eligible systematic literature review studies.

Figure 4.12: Chart showing the frequency of the relations & networks sub-components

Relationships between, and leadership within, health system organisations influence the implementation process. Facilitators and barriers include the clarity of roles and responsibilities, leadership strength, hierarchies present within and between organisations, the existence of social networks, community and personnel cohesion, team dynamics in an organisation, power relations, and the areas where power is centralised (George *et al.*, 2011; Peters *et al.*, 2011; Busza *et al.*, 2012; Spiegel *et al.*, 2012; Aniteye and Mayhew, 2013; Choy *et al.*, 2013; Zulu *et al.*, 2014; El-Jardali *et al.*, 2014; Ishijima *et al.*, 2014; Ollerhead and Osrin, 2014; Tomlinson, Hunt and Rotheram-Borus, 2018; Tran Ngoc *et al.*, 2018; Mbau and Gilson, 2018; Raney *et al.*, 2019). Supportive relationships between stakeholders (for example, innovation companies, health facilities, patients and policymakers) and between personnel can facilitate implementation (L A. Palinkas *et al.*, 2015; Blackstone *et al.*, 2017; Mijumbi-Deve and Sewankambo, 2017; Raney *et al.*, 2019). Furthermore, different management styles influence implementation. Mbau and Gilson (2018) distinguish between three management styles – authoritarian, participative or consultative. Further barriers to implementation occur due to relationships between organisations in the health system that are sub-optimally integrated and poorly co-ordinated, thus leading to a fragmented health system (Davy and Patrickson, 2012; Catalani *et al.*, 2014; Folaranmi, 2014; Vasan *et al.*, 2015; Puchalski Ritchie *et al.*, 2016; Tran Ngoc *et al.*, 2018).

The evaluation and feedback component examines the adequacy of monitoring and evaluation (George *et al.*, 2011; Pérez-escamilla *et al.*, 2012; Folaranmi, 2014; Ollerhead and Osrin, 2014; Fowkes *et al.*, 2016; Puchalski Ritchie *et al.*, 2016; Tomlinson, Hunt and Rotheram-Borus, 2018), including (i) how well results are communicated to stakeholders, (ii) the effectiveness of record keeping, (iii) whether meaningful and consistent indicators are used, and (iv) the timeliness and frequency of feedback (George *et al.*, 2011; Folaranmi, 2014; Ollerhead and Osrin, 2014; Bazos *et al.*, 2015; Mbau and Gilson, 2018).

Collaborations include the involvement of stakeholders, such as institutions, communities and health providers (Mijumbi-Deve and Sewankambo, 2017; Baker *et al.*, 2018; Spagnolo *et al.*, 2018). Interprofessional collaborations, for example, between researchers and health providers, and

partnerships, such as public and private partnerships or international partnerships, also influence implementation (Hamel and Schrecker, 2011; Leon, Schneider and Daviaud, 2012; Pérez-escamilla *et al.*, 2012; Zepeda-Burgos, Storch and Ballabriga, 2014; Jha *et al.*, 2016; Puchalski Ritchie *et al.*, 2016; Aamir *et al.*, 2018; Tran Ngoc *et al.*, 2018).

The communication component considers communication channels across the health system. Facilitators and barriers relating to communication include interpersonal communication practices, the complexity and frequency of communication, and the effectiveness of the communication style and structure, which could be top-down, siloed or facilitated (Nzinga *et al.*, 2009; Pérez-escamilla *et al.*, 2012; Zulu *et al.*, 2014; Jha *et al.*, 2016; Blackstone *et al.*, 2017; Mbau and Gilson, 2018; Nielsen *et al.*, 2018).

4.3.5.5 Actors

The facilitators and barriers of the actors component, as extracted from the eligible studies, include (i) culture, (ii) incentives and motivation, (iii) attitudes, and (iv) beliefs. Figure 4.13 displays the frequency with which each *actors* sub-component appeared in the eligible systematic literature review studies.

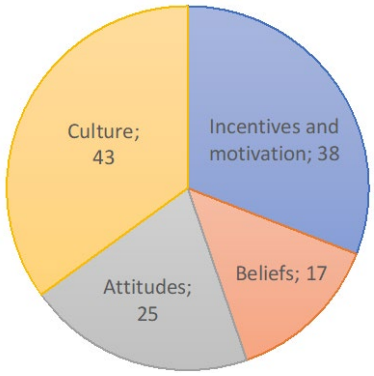


Figure 4.13: Chart showing the frequency of the actors sub-components

Incentives and motivations for actors to embrace the implementation of an innovation can be monetary, recognition or appreciation, a decrease in workload, self-benefits such as satisfaction or prospects of career benefits, empowerment, or a sense of ownership of the innovation (Nzinga *et al.*, 2009; Bhutta *et al.*, 2009; George *et al.*, 2011; Spiegel *et al.*, 2012; Bergström *et al.*, 2012, 2015; Busza *et al.*, 2012; L A. Palinkas *et al.*, 2015; Zulu *et al.*, 2015; Iwelunmor *et al.*, 2016; Jha *et al.*, 2016; Cunningham *et al.*, 2016; Hoffman *et al.*, 2016; Kiberu, Mars and Scott, 2017; McRobie *et al.*, 2017; Aamir *et al.*, 2018; Abejirinde *et al.*, 2018; Spicer *et al.*, 2018; Tran Ngoc *et al.*, 2018; Baker *et al.*, 2018; Young *et al.*, 2019).

The beliefs component considers the conflicting beliefs among actors, beliefs about the health system, and the belief of the actors about their capabilities. Actors' attitudes influence innovation implementation. An actor's attitude could be arrogant, trusting, fearful, confident, enthusiastic or committed, among others (Nzinga *et al.*, 2009; Bergström *et al.*, 2012, 2015; Busza *et al.*, 2012; Ollerhead and Osrin, 2014; El-Jardali *et al.*, 2014; Ishijima *et al.*, 2014; Fritz, Tilahun and Dugas, 2015; Puchalski Ritchie *et al.*, 2016; Bigna, Plottel and Koulla-Shiro, 2016; Fowkes *et al.*, 2016; Shroff *et al.*, 2017; Abejirinde *et al.*, 2018; Spagnolo *et al.*, 2018; Mbau and Gilson, 2018; Raney *et al.*, 2019; Shayan, Kiwanuka and Nakaye, 2019; Young *et al.*, 2019).

Attitudes can be conflicting and are influenced by how actors identify with the organisation, by an actor's interest in the innovation and by the sense of accountability that an actor feels (Nzinga *et al.*, 2009; Yamey, 2012; Puchalski Ritchie *et al.*, 2016; Uzochukwu *et al.*, 2016; Kiberu, Mars and Scott, 2017; Abejirinde *et al.*, 2018; Spagnolo *et al.*, 2018; Shayan, Kiwanuka and Nakaye, 2019).

Culture considers the work and organisational cultures to which actors are exposed. Culture encompasses organisational agendas, values or missions; health worker norms; social pressures, which can include discrimination and stigma; a culture of learning; resistance to change; and a culture of compliance (Nzinga *et al.*, 2009; Hamel and Schrecker, 2011; George *et al.*, 2011; Busza *et al.*, 2012; El-Jardali *et al.*, 2012, 2014; Aniteye and Mayhew, 2013; Ollerhead and Osrin, 2014; L A Palinkas *et al.*, 2015; Bergström *et al.*, 2015; Uzochukwu *et al.*, 2016; Bigna, Plottel and Koulla-Shiro, 2016; Alto and Petrenko, 2017; Kiberu, Mars and Scott, 2017; Bardosh *et al.*, 2017; Glasziou *et al.*, 2017; Nielsen *et al.*, 2018; Shayan, Kiwanuka and Nakaye, 2019).

4.3.5.6 Resources

The facilitators and barriers of the resource's component, as extracted from the eligible studies, are divided into (i) time, (ii) physical, (iii) financial and (iv) human. Figure 4.14 displays the frequency with which each *resources* sub-component appeared in the eligible systematic literature review studies.

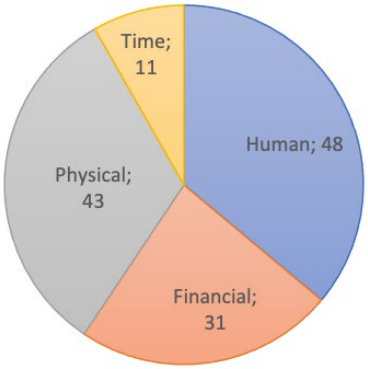


Figure 4.14: Chart showing the frequency of the resources sub-components

Human resource shortages afflict LMIC health systems. Healthcare staff are overburdened, the turnover of staff is high, and the allocation of health workers within and between countries is inadequate (Nzinga *et al.*, 2009; Peters *et al.*, 2011; Pérez-escamilla *et al.*, 2012; El-Jardali *et al.*, 2014; Fowkes *et al.*, 2016; Jha *et al.*, 2016; Alto and Petrenko, 2017; Shields-Zeeman *et al.*, 2017; Abejirinde *et al.*, 2018; Spagnolo *et al.*, 2018). Another human resources barrier to implementation is the mobility of staff and patients (Cunningham *et al.*, 2016; McRobie *et al.*, 2017). Human resource implementation facilitators include task shifting and the presence of a 'champion' individual (George *et al.*, 2011; Choy *et al.*, 2013; Ovbiagele, 2015; Jha *et al.*, 2016; Bardosh *et al.*, 2017; Mijumbi-Deve and Sewankambo, 2017; Abejirinde *et al.*, 2018; Nielsen *et al.*, 2018; Spicer *et al.*, 2018).

Financial resource constraints include a lack of local, sustainable funding sources (Leon, Schneider and Daviaud, 2012; Folaranmi, 2014; Kiberu, Mars and Scott, 2017; Tran Ngoc *et al.*, 2018). Furthermore, financial resources in LMICs are often inadequately distributed, and existing funding structures are often siloed and disease-specific, with a historical focus on donor funding (Fowkes *et al.*, 2016). Other financial barriers include informal payments and patients' inability to afford care (Bergström *et al.*, 2012, 2015; Glasziou *et al.*, 2017).

Time constraints inhibit implementation, and time constraints are closely linked to human resource constraints. Time constraints include a lack of time to attend training, long patient waiting or travelling times, and the time-consuming nature of implementing certain innovations (Ollerhead and Osrin, 2014; Fowkes *et al.*, 2016; Puchalski Ritchie *et al.*, 2016; Alto and Petrenko, 2017; Mijumbi-Deve and Sewankambo, 2017; Baker *et al.*, 2018; Spagnolo *et al.*, 2018).

Physical resource constraints range from inadequate drug storage facilities, cold chain issues, unreliable power, poor internet and mobile signal connectivity, lack of access to operational equipment, ambulance shortages, medicine stock-outs to insufficient resources necessary for equipment repair and maintenance (Graham and Mishra, 2011; Spiegel *et al.*, 2012; Busza *et al.*, 2012; Ollerhead and Osrin, 2014; Catalani *et al.*, 2014; El-Jardali *et al.*, 2014; Bazos *et al.*, 2015; Braddick *et al.*, 2015; Fritz, Tilahun and Dugas, 2015; Puchalski Ritchie *et al.*, 2016; Bigna, Plottel and Koulla-Shiro, 2016; Cunningham *et al.*, 2016; Grover *et al.*, 2017; Huang, Blaschke and Lucas, 2017; Kiberu, Mars and Scott, 2017; Diaconu *et al.*, 2017; Aamir *et al.*, 2018; Raney *et al.*, 2019; Young *et al.*, 2019). Physical resources are often inadequately procured and distributed (Fowkes *et al.*, 2016; Puchalski Ritchie *et al.*, 2016). The capacity of the existing health system infrastructure is usually insufficient in LMICs (Peters *et al.*, 2011; Yamey, 2012; Khatib *et al.*, 2017).

4.3.5.7 Context

The facilitators and barriers of context, as extracted from the eligible studies, can be divided into (i) socio-demographic, (ii) environmental, (iii) epidemiological, (iv) political, (v) economic and (vi) socio-cultural. Figure 4.15 displays the frequency with which each *context* sub-component appeared in the eligible systematic literature review studies.

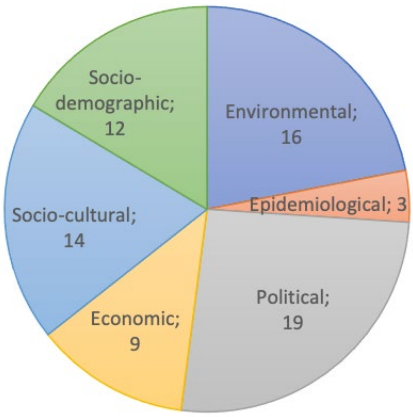


Figure 4.15: Chart showing the frequency of the context sub-components

The environmental component of context includes (i) the distribution of health facilities, (ii) the distance between facilities and between the communities being served by a facility, (iii) the remoteness of a facility, (iv) the transportation systems linking health facilities to each other and communities, (v) the type of terrain present where the innovation is being implemented, (vi) the weather conditions (including the humidity levels, temperatures and natural disasters), and (vii) the altitude and levels of dust in the environment in which the innovation is being implemented (Bhutta *et al.*, 2009; Busza *et al.*, 2012; Chopra *et al.*, 2012; Murray, Familiar, *et al.*, 2013; L A Palinkas *et al.*, 2015; Cunningham *et al.*, 2016; Blackstone *et al.*, 2017; Glasziou *et al.*, 2017; Shields-Zeeman *et al.*, 2017; Spagnolo *et al.*, 2018). Epidemiology describes the distribution and frequency of

diseases; this links to the *institutions* concept that describes competing health priorities in terms of diseases (Graham and Mishra, 2011).

The political component comprises (i) the political regime and its stability, (ii) the leadership in the ministry of health, (iii) ideological beliefs, (iv) the presence of politicised issues, such as abortion, homosexuality or prostitution, (v) the presence of corruption, (vi) conflict, which can lead to unregulated markets, uncoordinated aid work, and security issues, and (vii) the political climate, both internationally and locally (Haines, Kuruvilla and Borchert, 2004; Busza *et al.*, 2012; Spiegel *et al.*, 2012; Aniteye and Mayhew, 2013; Ongolo-Zogo *et al.*, 2014; Wilson *et al.*, 2014; Bergström *et al.*, 2015; Puchalski Ritchie *et al.*, 2016; Bertone *et al.*, 2018).

The economic concept describes an area's economic stability and status, as well as community, national and international financial conditions (Busza *et al.*, 2012; Yamey, 2012; Ollerhead and Osrin, 2014; Glasziou *et al.*, 2017).

Socio-cultural factors include (i) social and gender norms, (ii) cultural beliefs such as satanism and witchcraft, (iii) religious beliefs, (iv) historical contexts (such as the presence of exploited or marginalised populations), and (v) traditional or indigenous health practices (Busza *et al.*, 2012; Davy and Patrickson, 2012; Aniteye and Mayhew, 2013; Choy *et al.*, 2013; Murray, Shannon, *et al.*, 2013; Huang, Blaschke and Lucas, 2017; Bertone *et al.*, 2018; Mbau and Gilson, 2018).

Socio-demographic factors that facilitate or hinder implementation include the languages spoken, immigration status, literacy of the population, age groups, and employment status (Haines, Kuruvilla and Borchert, 2004; Nzinga *et al.*, 2009; Ollerhead and Osrin, 2014; Wilson *et al.*, 2014; Cunningham *et al.*, 2016; Glasziou *et al.*, 2017; Aamir *et al.*, 2018; Abejirinde *et al.*, 2018).

4.3.6 Discussion of Results

Figure 4.16 displays the frequency with which each concept appeared in the eligible systematic literature review studies. There are no substantial variations between the frequency of a concept being identified as a barrier or facilitator to implementation in LMICs.

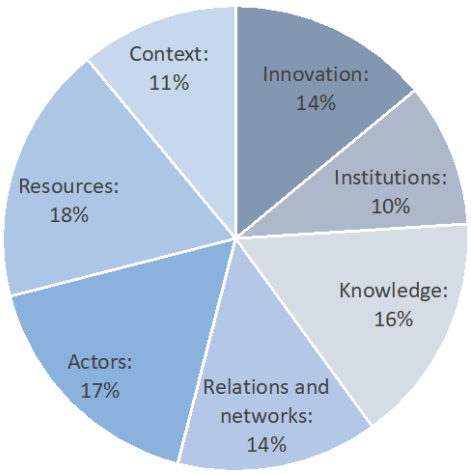


Figure 4.16: Chart showing the frequency with which the concepts were mentioned as either barriers or facilitators

With *resources* being the most frequently mentioned concept, it is evident that the resource constraints in LMICs need improvements. The human resources sub-component was most

frequently identified as a barrier or facilitator within the *resources* concept. Key stakeholders, particularly governments, need to address the resources gap for innovations to be successfully and sustainably implemented. When assessing the financial resources, it is important to assess the sustainability of the proposed funding source, specifically when considering donor funding. Unsustainable funding sources may result in an innovation not being successfully implemented. Persistently failing to implement an innovation successfully can affect workers' morale (implementation is time-intensive) and patients' trust, thus resulting in additional barriers during subsequent implementation processes.

The policy environment was the most frequently mentioned sub-component of the *institutions* concept. This emphasises the importance of the existence of clear policies enabling innovation implementation, and the importance of the policies aligning with one another, with the country's health goals and with the innovation's guidelines. *Context* is a concept that multiple studies have focused on; this highlights the importance of understanding the LMIC environment in which the implementation process is taking place. The sub-component in the *context* concept, which occurred the most frequently, was the political context. The political context is not always the first thing that comes to mind when considering the implementation context; however, LMICs could encompass certain unique political circumstances, which influence implementation, and political support for an innovation. These include the political stability in a country and the presence of corruption and politicised issues.

Within the *knowledge* concept, education is the sub-component emphasised most frequently as a barrier or facilitator to implementation. In education, the training surrounding the proposed innovation is highlighted. For successful and sustainable implementation, health cadres need to be effectively trained. Within LMICs, there tends to be a high turnover and mobility of healthcare workers, which means that the training surrounding the innovation should be easy, accessible and frequent. Training to use or implement an innovation could be included in the curricula taught at the universities or from typical training resources, such as manuals and workshops, to case-based and simulation learning (which was proved successful in Bihar, India (Raney *et al.*, 2019)). When considering the *innovation* concept, the innovation's functionality is the most frequently occurring sub-component. The innovation's functionality should be needs-based and effective in the environment in which it is being implemented. Furthermore, the innovation must be user-friendly.

Within the *actors* concept, culture is the sub-component most frequently referred to. Organisational culture is often studied in implementation science. Culture should be considered in the context of the organisation where the innovation is being implemented and within the other organisations that can affect the implementation process (for example, the culture of policymakers, researchers or innovation companies). These organisations might have competing agendas, pressures and norms that influence implementation. With so many different stakeholders present in the implementation process, there must be relations & networks present within and between stakeholder organisations. Effective interdisciplinary communication, monitoring and evaluation, and strong leadership are some aspects that affect implementation in the *relations & networks* concept.

4.3.7 Interpretation of the Results in the Context of Wider Published Literature

In order to interpret the results of this review in the context of the broader health implementation landscape, two commonly used health implementation frameworks were considered. These frameworks are the Consolidated Framework for Implementation Research (CFIR) (Damschroder *et*

al., 2009) and the integrated Promoting Action of Research Implementation in Health Services (i-PARIHS) framework (Harvey and Kitson, 2016).

The CFIR was developed by integrating fundamental concepts from existing implementation theories and can be used to evaluate implementation scenarios (Damschroder *et al.*, 2009). The CFIR comprises five concepts, which are further broken down into constructs. The concepts present in the CFIR are: (i) the characteristics of the intervention, (ii) the characteristics of the individual using it, (iii) the outer setting, (iv) the inner setting, and (v) the process (Damschroder *et al.*, 2009).

The i-PARIHS framework is an extension of the PARIHS framework, which was initially published in 1998 (Harvey and Kitson, 2016). The PARIHS framework was one of the earliest to emphasise the importance of context and to definitively describe the complex and multi-dimensional aspects of implementation (Harvey and Kitson, 2016). The i-PARIHS framework was developed to reflect the new research in implementation science. The i-PARIHS framework consists of four core concepts: (i) innovation, (ii) recipients, (iii) context, and (iv) facilitation (Harvey and Kitson, 2016).

Both the CFIR and the i-PARIHS frameworks consist of concepts describing the facilitators or barriers associated with innovation implementation. The frameworks describe the actors involved in the implementation process, the innovation itself, and the context (at varying levels) in which the innovation is being implemented. The results from the systematic literature review cover all aspects of both frameworks, thus validating the review results. The systematic literature review results place greater emphasis on the concepts that the CFIR and i-PARIHS classified as “context” or “setting”. *Resources*, *knowledge*, *relations & networks* and *institutions* were separated from the context concept, thus allowing for them to be analysed in more detail. The lack of focus on specific contextual concepts by the CFIR and i-PARIHS is likely due to the different barriers and facilitators present in LMICs compared to HICs. This is particularly apparent in the *resources* concept, which, as shown in Figure 4.16, is often cited as a significant barrier to implementation in LMICs.

4.4 CHAPTER 4: CONCLUSION

In this chapter, a systematic literature review was conducted to answer the question: *What are the facilitators and barriers to implementing health innovations in LMICs?* During the first stage of the systematic literature review, the specific literature intersection and the inclusion criteria were defined. Thereafter, the studies identified within the literature intersection were described, and the papers published after the initial search were briefly discussed. Once the studies in the specific literature intersection had been identified, the studies were screened for eligibility. The eligible studies were analysed, and the barriers and facilitators identified in the eligible studies were extracted. The extracted barriers were categorised according to the concepts presented in the Conceptual Health Innovation System framework from Chapter 3. The consolidated, categorised results were then discussed and interpreted in the broader health implementation landscape context. In the next chapter, existing assessment approaches will be investigated to determine the most effective approach to assess health innovation implementation in LMIC health systems. An approach will be selected to achieve the study’s objectives: to develop an assessment approach that enables a practical and holistic assessment of the facilitators and barriers to implementation present in an LMIC health innovation system.

Chapter 5 Requirement Specifications for the LMIC Health Innovation Implementation Assessment Approach

In this chapter, the requirement specifications that will enable the achievement of the study's aim of *developing an assessment approach that is able to evaluate health innovation systems and their capability to implement evidence-based innovations successfully and sustainably in LMICs,* are determined. The results from the conceptual literature review of Chapter 3, in which a health innovation system is defined, and the results from the systematic literature review of Chapter 4, in which the barriers and facilitators to implementation in LMICs are identified and used to develop the requirement specifications. Based on these requirement specifications, maturity models were identified as an appropriate approach. The chapter thus ends with a comparative review of existing health innovation maturity models and a discussion concerning the general types of maturity models.

5.1 REQUIREMENT SPECIFICATIONS

Requirement specifications must be developed to guide the development of a solution that can be used to evaluate the sustainable implementation of evidence-based innovations in LMIC health systems. Requirement specifications are the specific functions that a solution must be able to perform; they assist with providing a scope of what a solution should contain (Boehm, 1984). Van Aken (2003) has identified four categories according to which requirement specifications can be classified: (i) functional requirements, (ii) user requirements, (iii) boundary conditions, or (iv) design restrictions. In the following sub-sections, the requirement specification categories will be described, and the specific requirement specifications for this study will be identified for each category. The research presented in Chapter 1, Chapter 3 and Chapter 4 is used as the foundation from which the requirement specifications are extracted.

5.1.1 Functional Requirements

Functional requirements describe how a solution should operate; functional requirements are the core performance demands, which describe the functions that must be performed and their expected outputs (Van Aken, 2003; Sommerville, 2016). Meeting the functional requirements will support the achievement of the study's aim. In Table 5.1, the functional requirements of this study are described.

Table 5.1: Functional requirement specifications

	Functional Requirement
FR1	The solution should contribute to understanding the properties of an implementation process (i.e., searching for, selecting, or designing an innovation; preparing for implementation; implementing an innovation; and sustaining an innovation).
FR2	The solution should be multi-dimensional, describing and enabling an understanding of a health innovation landscape: i. The solution should contain a description of health system concepts; and ii. The solution should contain a description of innovation system concepts.
FR3	The solution should be applicable to and should enable the description of an LMIC context.
FR4	The solution should contribute to understanding the capability of a system to implement a health innovation: i. The solution should encompass the potential barriers and enablers to implementing a health innovation; ii. The solution should enable the identification of implementation facilitators, and barriers present within the system; and iii. The solution should define a path towards improving the success and sustainability of innovation implementation (i.e., an evolutionary path).

The functional requirements are derived from the literature reviews conducted in Chapter 3 and Chapter 4 and from the study's aim, objectives and background, as described in Chapter 1. FR1 originates from the study's problem statement and aim (Sections 1.2 and 1.3, respectively). It is necessary to understand what an implementation process consists of to understand why implementing a health innovation is unsuccessful, as outlined in FR1. The second functional requirement, FR2, emphasises the need for systems thinking and arises from the problem statement (Section 1.2) and the conceptual literature review of Chapter 3. As discussed in Chapter 3, Section 3.2, systems thinking is the capability to view a system as a whole and recognise that it contains multiple interdependent and interconnected parts, not just individual components (Sterman, 2001).

FR3 is derived from the research gap, scope and the problem statement described in Chapter 1 – the contextual scope considered in the study is LMICs. FR4 originates from the aim of the study (Section 1.3), the research gap (Section 1.1) and the systematic literature review results described in Chapter 4. To achieve the study's aim, it is necessary to understand and evaluate the system's capability of the system under consideration, to implement an identified health innovation.

5.1.2 User Requirements

User requirements consider the solution's usability, as identified from the perspective of the prospective users (Van Aken, 2003). In Table 5.2, the user requirements that a solution would need to meet are described. Meeting the user requirements will ensure that the solution is useful and usable and will support the achievement of the study's aim.

Table 5.2: User requirement specifications

	User Requirement
UR1	The solution should contain clear explanations and definitions and is user-friendly while maintaining an adequate level of complexity to assess implementation in a health innovation system.
UR2	The solution should enable users to benchmark innovations and/or implementation strategies.
UR3	The solution should be able to be used as a decision support tool and should be able to enlighten those using it by: i. Informing the user's ability to select an innovation; ii. Enabling the user to identify gaps in a health system and/or in an innovation; and/or iii. Support the user to understand what went wrong in an implementation process.
UR4	The solution should be able to inform change, enabling the user to develop improvement initiatives by: i. Guiding the user to adapt (modify/adjust) a health innovation; ii. Guiding the user to adapt an implementation strategy; and/or iii. Guiding the user to adapt the adjustable components of a health innovation system.

The user requirements described in Table 5.2 were developed primarily from the sections of Chapter 1, namely, from the problem statement, aim, objectives, scope and study rationale and from the evaluation objectives described in Chapter 2 Section 2.3.3. In the following sub-section, the design space in which the solution should exist is considered.

5.1.3 Design Restrictions

Design restrictions are used to delineate the space in which the solution should be designed and the context in which it should be implemented (Van Aken, 2003; Sommerville, 2016). The design restrictions will ensure that the solution addresses the research gap, supporting achieving the study's aim. In Table 5.3, the design restrictions of this study are described.

Table 5.3: Design restriction specifications

	Design Restrictions
DR1	The user should be able to apply the solution to a variety of evidence-based health innovations.
DR2	The solution should be applicable to a broad range of LMIC contexts, and some principles within the solution may also be applicable to HICs.
DR3	The solution should enable a holistic assessment of a health innovation system. While the solution should facilitate a systems-level analysis, lower levels of analysis may still be possible.
DR4	The solution should provide a comprehensive view of the factors that act as facilitators and barriers during an implementation process in an LMIC.

The design restrictions are derived from the major themes of this study, namely: (i) evidence-based health innovations, (ii) the LMIC context, (iii) health innovation systems, and (iv) implementation. The design restrictions were identified from the literature reviews conducted in Chapter 3 and Chapter 4, as well as from the research gap, aim, objectives, scope and background of this study, described in Chapter 1.

DR1 is derived from the research gap identified in Section 1.1 and the problem statement in Section 1.2, in which the unsuccessful and unsustainable implementation of evidence-based health innovations is considered (i.e., implementation is considered). Despite the countless resources expended on creating innovative healthcare solutions, these innovations are often not successfully or sustainably implemented in the systems where and when they are needed (Denis et al., 2002); it

is thus necessary for the solution to be applied to numerous different types of evidence-based innovations.

DR2 is extracted from the scope (Section 1.5), the research gap (Section 1.1), and the systematic literature review presented in Chapter 4. The contextual focus of this study is LMICs; however, as established in Section 4.3.7, several concepts identified for the LMIC context have shared commonalities with HIC settings. DR3 is derived from Chapter 3, which investigates health and innovation systems. DR4 is obtained from the systematic literature review of Chapter 4, in which the facilitators and barriers to implementing health innovations are investigated. The boundaries within which the solution has to operate are considered in the following sub-section.

5.1.4 Boundary Conditions

Boundary conditions are the requirements that must be met unconditionally (Van Aken, 2003). Boundary conditions constrain the object or solution being designed and result from the system in which the design will be implemented or is being developed, e.g., the legal system (Sommerville, 2016). In Table 5.4, the boundary conditions of this study are described.

Table 5.4: Boundary condition specifications

	Boundary Conditions
BC1	The solution should be used ethically and abide by relevant ethical frameworks, such as bioethics principles (National Commission, 1979) or the Ethical Framework for Health Systems Research (Pratt and Hyder, 2019).
BC2	The solution should conform to relevant international health and innovation system regulations, including the relevant international laws, legislations and restrictions.
BC3	The solution should be interoperable with different settings, i.e., it should be able to function on digital platforms as well as through paper-based means.

The boundary conditions are developed mainly from the results of the systematic literature review described in Chapter 4. BC1 is derived from Section 4.3.5.1 and the principles of public health ethics described by Pratt and Hyder (2019); however, the solution is not intended to be an ethical guide, and the user should still consult with relevant experts and/or material. BC2 is derived from Section 4.3.5.2 of the systematic literature review; regulations include the laws, legislations and restrictions governing health system activities. However, the solution is not intended to be a regulatory guide; relevant experts and/or material should be consulted.

BC3 is derived from Section 4.3.5.1 of the systematic literature review. The factors that affect interoperability within a health system include the compatibility of a solution with existing resources (Huang, Blaschke and Lucas, 2017). As the solution is intended for use in LMIC settings, where there will not always be access to digital tools, the solution must be is able to function in both a digital and a paper-based format.

In the following section, the requirement specifications are used to assess the maturity model approach.

5.2 MATURITY MODELS TO MEET THE REQUIREMENT SPECIFICATIONS

With no existing approach able to sufficiently achieve the aim of the study (refer to the research gap in Section 1.1.3, Chapter 1), a novel research solution will be developed using the requirement specifications as a guide. Maturity models were identified as an appropriate approach for structuring the research solution. Maturity models are multi-staged models, which detail the evolution from an initial to a mature state of an organisation's, an individual's or a system's capabilities (Poeppelbuss *et al.*, 2011; Mettler and Blondiau, 2012).

5.2.1 Why Maturity Models?

A maturity model approach was chosen as the basis to develop the research solution due to its ability to meet the requirement specifications and, thus, the aim of *evaluating health innovation systems and their capability to implement evidence-based innovations successfully and sustainably in LMICs.* Maturity models' ability to address the requirement specifications is described in the following sub-sections.

5.2.1.1 Assessing Maturity Models Against the Functional Requirements

Maturity models are frequently used to determine the as-is capability of an organisation (Poeppelbuss *et al.*, 2011); this addresses FR4, which requires understanding a system's capability to implement an innovation. Maturity models are also able to address the improvement path requirement described in FR4 – maturity models illustrate a direction for development towards the desired state (Mettler and Blondiau, 2012) and thus enable the development of improvement strategies (Tocto-Cano *et al.*, 2020). Additionally, the maturity model approach does not consist of predefined categories and is easily adaptable to different scenarios, as illustrated by the multiple sectors in which it has been used (Lee, Gu and Jung, 2019). The adaptability of the maturity model approach allows for the achievement of FR1, FR2, and FR3 – the implementation process in an LMIC health innovation landscape can easily be portrayed using the adaptable maturity model approach.

5.2.1.2 Assessing Maturity Models Against the User Requirements

Maturity models can be designed in a user-friendly manner (UR1), illustrated by their practical use in industry and academia (Rosenstock, Johnston and Anderson, 2000). Furthermore, they are usable as a benchmarking tool (Khoshgoftar and Osman, 2009; Introna *et al.*, 2014), meeting UR2, which requires the solution to benchmark innovations and implementation strategies. Additionally, maturity models have been used as decision-support tools to inform change (Guédria, Naudet and Chen, 2011; Orenstein *et al.*, 2019), which addresses UR3 and UR4.

Maturity models are "*recognized tools for the stepwise and systematic development and/or improvement of skills, processes, structures or general conditions of an organization*" (Blondiau, Mettler and Winter, 2015, p. 758). The purpose of a maturity model is to guide improvement activities and enable the evolution of the capabilities being assessed (Mettler and Rohner, 2009). Another benefit of maturity models is their ability to provide formality to improvement initiatives and support the prioritisation of these initiatives (Becker, Knackstedt and Pöppelbuß, 2009; Mettler, 2010). Hence maturity models are an appropriate approach for informing change and supporting decision-making.

5.2.1.3 Assessing Maturity Models Against the Design Restrictions

As discussed for FR1, FR2 and FR3, maturity models are easily adaptable to different scenarios; this adaptability makes provision for DR1 and DR2. The maturity model approach can be adapted to be applicable to a variety of evidence-based health innovations (DR1) and a broad range of LMIC contexts (DR2). The structure of maturity models, namely their use of domains and/or capability areas (De Bruin *et al.*, 2005), enables the achievement of DR3 and DR4. Maturity models assess the maturity of a domain; maturity, which can be defined as "*the state of being fully grown or developed*" (Oxford Dictionaries, 2019d, p.1), is assessed based on a specified set of criteria or capability areas (De Bruin *et al.*, 2005). The domain's structure can be leveraged to ensure that the maturity model describes a holistic health innovation system (DR3). The capability areas can be leveraged to ensure the implementation facilitators and barriers are comprehensively covered (DR4).

5.2.1.4 Assessing Maturity Models Against the Boundary Conditions

The boundary conditions of the study are more generic than the previously discussed requirement specifications. The maturity model should be used ethically (BC1) and adhere to relevant regulations (BC2); these depend on the user, not necessarily on the maturity model itself. Maturity models are usable electronically and in paper-based format; hence maturity models are able to achieve BC3.

It is concluded that maturity models are suitable for this study as they can effectively meet the requirement specifications stipulated in Section 5.1. In the following section, existing health innovation maturity models will be explored.

5.2.2 Existing Health Innovation Maturity Models: Is a New One Needed?

An overview of the existing models is provided to better understand the types of maturity models within the health innovation implementation research field. Two of the study's overarching themes – health and innovation – guide the search for maturity model literature. First, health maturity models are explored through a descriptive review of the literature, as presented in Section 5.2.2.1. In Section 5.2.2.2, innovation maturity models are explored through a descriptive literature review. Lastly, the intersection of health and innovation maturity models will be investigated, and the specific maturity models identified in this intersection will be investigated in relation to the requirement specifications.

5.2.2.1 Health Maturity Models

A descriptive review of health maturity models was conducted using the Scopus database. The Scopus advanced search mode was utilised to search for *health maturity models* with relevant synonyms; the full search strings are presented in Figure E-1, Appendix E. The search was conducted in April 2021 and was not restricted by date, field, or study type; however, only studies in English were investigated. The Scopus search returned 475 results, with publication dates ranging from 1975 to 2021. The majority of the studies are from the medical field, accounting for 185 of the returned documents, followed by the computer science discipline with 169 documents, and engineering with 148 documents. Since 2007, there has been a steady increase in the number of papers published, with 2019 recording the highest number of health maturity model related documents published in a year.

VOSviewer was used to gain further descriptive insights into the resulting 475 documents. Figure 5.1 shows the network of keywords that the authors specified for their studies. The keywords are connected through co-occurrences (the number of times the keywords are used together); the size of the nodes represents how frequently the keywords occur. From these keywords, the major application areas of health maturity models are (i) management, (ii) eHealth, (iii) quality improvement, (iv) health information systems, and (v) primary care.

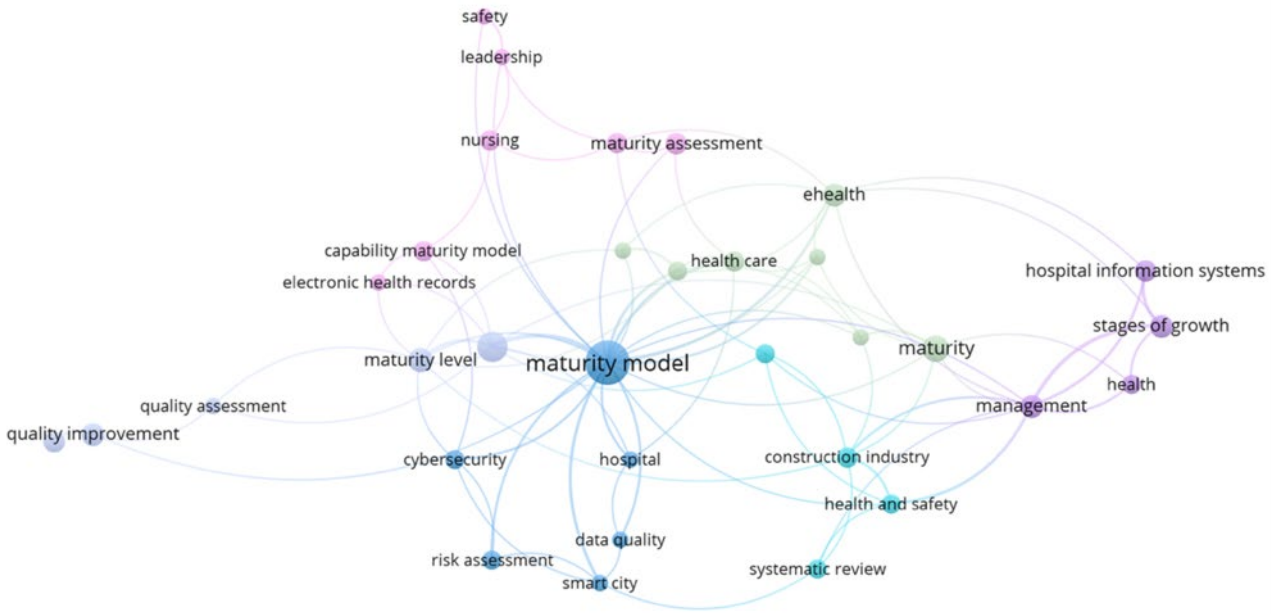


Figure 5.1: Frequency of keywords specified by authors, health maturity model search

5.2.2.2 Innovation Maturity Models

A descriptive review of innovation maturity models was conducted using the Scopus database. The Scopus advanced search mode was utilised to search for *innovation maturity models* with relevant synonyms; the entire search strings are presented in Figure E-2, Appendix E. The search was conducted in April 2021 and was not restricted by date, field or study type; however, only studies in English were investigated. The Scopus search returned 468 results, with publication dates ranging from 1992 to 2021. Since 2004, a steady increase in the number of papers published relating to the innovation maturity models was noted, with 2020 recording the highest number of documents published in a year. Most of the studies returned are from the computer science field, with 182 documents, followed by the business management and accounting field, with 168 documents, and the engineering field, with 153 documents.

VOSviewer was used to gain further descriptive insights into the 468 search results returned. Figure 5.2 shows the network of keywords that the authors specified for their studies. The keywords are connected through co-occurrences (the number of times the keywords are used together). The size of the nodes represents how frequently the keywords occur. From the keywords, the major application areas of innovation maturity models are (i) knowledge management, (ii) open innovation, (iii) innovation management, (iv) industry 4.0, and (v) digital transformation.

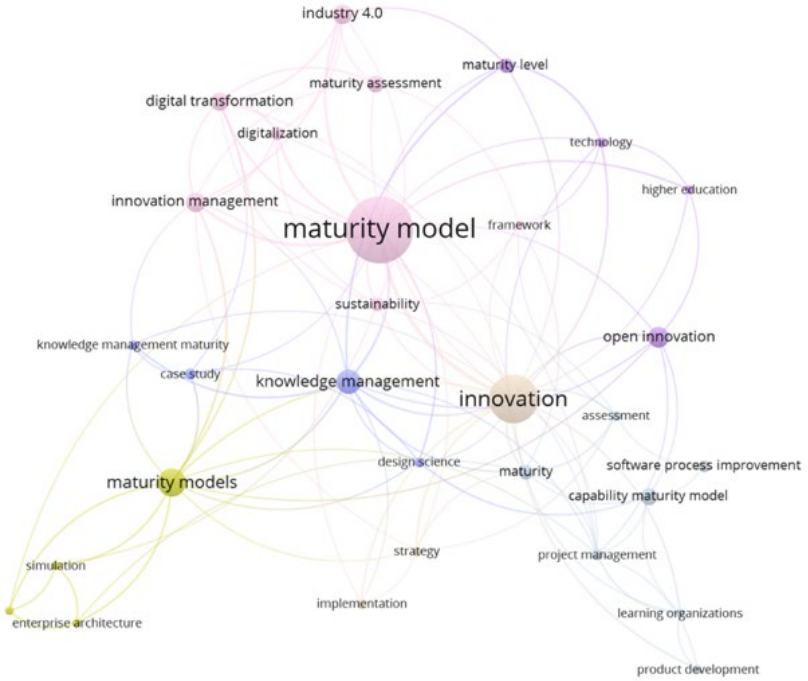


Figure 5.2: Frequency of keywords specified by authors, innovation maturity model search

5.2.2.3 Health Innovation Maturity Models

For the next phase of exploring existing maturity models, maturity models specific to the major study themes are investigated. The intersection of the major themes in this review is portrayed in Figure 5.3. Maturity models covering health innovation implementation in LMICs will be considered. The Scopus database was used to perform this search; the search terms used were *health innovation implementation maturity model*, with relevant synonyms; the full search strings are presented in Section E.1, Appendix E. The search was conducted in April 2021 and was not restricted by date, field or study type. Zero search results were returned, indicating that no maturity model covering the themes shown in Figure 5.3 exists.

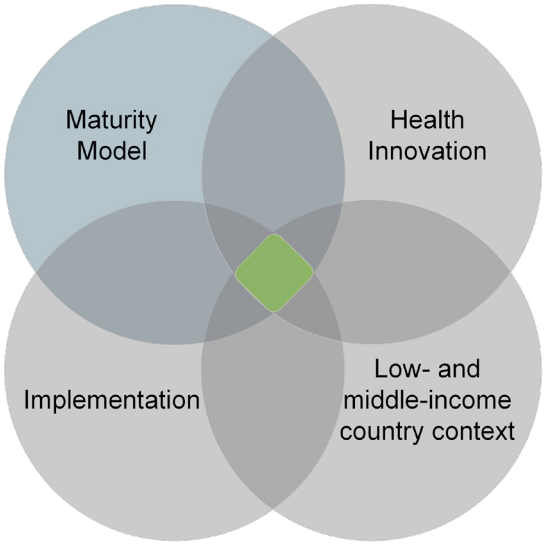


Figure 5.3: Venn diagram showing the intersection of the study's major themes with the proposed assessment approach

With the search for a maturity model in the major study themes returning zero results, the search was expanded by excluding the *LMIC context* and *implementation* search criteria, as described in Figure 5.4.

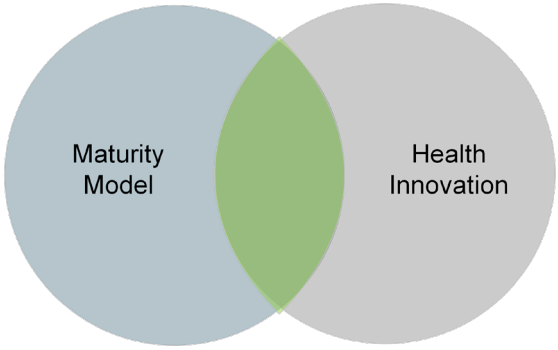


Figure 5.4: Venn diagram showing the expanded search criteria within the proposed assessment approach

The Scopus advanced search mode was utilised. The search terms used for this review are presented in Table 5.5, while the full search strings entered into Scopus are presented in Section E.1, Appendix E. The search was conducted in April 2021 and was not restricted by date, field or study type.

Table 5.5: Search terms used to investigate existing health innovation maturity models

Health **OR** Healthcare	**AND**	Innovation **OR** Evidence-based practice(s) **OR** Evidence-based intervention(s)	**AND**	Maturity model **OR** Maturity grid **OR** Maturity matrix **OR** Maturity assessment **OR** Maturity level(s)

The search returned 48 results. The publication dates of the results ranged from 2003 to 2021. The majority of the studies returned are from the computer science field, medical discipline, and social sciences field. Each of the 48 results was investigated further, and these documents were screened against the following exclusion criteria:

i. The study does not use an existing maturity model;
ii. The study does not develop or present a maturity model; or
iii. The study is not in English.

After applying the exclusion criteria to each of the 48 results, nine studies remained in which maturity models were used, developed or presented. An additional two models were identified through a search of maturity models in the *Implementation Science* journal[8]. The resulting 11 maturity models considered for further investigation are described in Table 5.6.

[8] https://implementationscience.biomedcentral.com/

Table 5.6: Health innovation maturity models

Maturity Model Title	Description	Maturity model's Reference
High Reliability Health Care Maturity (HRHCM)	The HRHCM was developed to assess high reliability in healthcare facilities. The domains within the model are (i) leadership, (ii) safety culture, and (iii) Robust Process Improvement® (Sullivan *et al.*, 2016). The maturity of each domain is assessed according to the four levels of maturity, from the least optimal stage, beginning, to the most optimal stage, approaching.	(Sullivan *et al.*, 2016)
Maturity models in hospitals	In their study, Blondiau, Mettler and Winter (2015) consider the application of three hospital maturity models, which the authors had previously developed, in terms of the following: (i) the maturity model for measuring the information technology capability of hospitals, (ii) the maturity model to measure effectiveness and reliability of a hospital's supply management procedures, and (iii) the maturity model to assess collaborative behaviour in hospitals (Blondiau, Mettler and Winter, 2015).	(Blondiau, Mettler and Winter, 2015)
Maturity Model for Enterprise Interoperability (MMEI)	Benedict *et al.* (2016) use the MMEI to evaluate eHealth platforms. MMEI has three domains that are assessed from level 0 to 4, namely: (i) the conceptual domain, (ii) the technological domain, and (iii) the organisational domain. Within each domain, there are common sub-domains that should be assessed, namely, business, process, service and data (Benedict *et al.*, 2016). In order to determine the maturity level of an eHealth platform, interview and questionnaire methodologies are used (Benedict *et al.*, 2016).	(Benedict *et al.*, 2016)
Capability Maturity Model (CMM) to assess electronic health records	The maturity model used by Schiza *et al.* (2015) is the CMM and is used to assess the implementation of an electronic health record at a national level. The CMM assesses the system using five maturity levels, where level 1 indicates initial system maturity and level 5 indicates optimal maturity (Schiza *et al.*, 2015).	(Schiza *et al.*, 2015)
Economic Enterprise Risk Management in Health Care ($E^2RM_{health\ care}$)	The $E^2RM_{health\ care}$ was developed to assess the enterprise risk management within health systems and the risk strategies present within health organisations (da Silva Etges *et al.*, 2018). The domains assessed by the model are founded on the implementation timeline of the enterprise risk management strategies. The domains are (i) baseline, (ii) education, (iii) quantitative, and (iv) governance (da Silva Etges *et al.*, 2018). There are four maturity levels used in the model: (i) level 1: not commenced, (ii) level 2: novice, (iii) level 3: partially achieved, and (iv) level 4: cutting edge (da Silva Etges *et al.*, 2018).	(da Silva Etges *et al.*, 2018)
Maturity Model for Integrated Care (MMIC)	Baltaxe *et al.* (2019) use the MMIC to assess the system's maturity in which the integrated care services are being implemented. The MMIC is made up of twelve dimensions: (i) Readiness to Change, (ii) Structure & Governance, (iii) Information & eHealth Services, (iv) Standardisation and Simplification, (v) Finance and Funding, (vi) Removal of Inhibitors, (vii) Population Approach, (viii) Citizen Empowerment, (ix) Evaluation Methods, (x) Breadth of Ambition, (xi) Innovation Management, and (xii) Capacity Building (Expert Group on Health Systems Performance Assessment, 2017; Baltaxe *et al.*, 2019).	(Baltaxe *et al.*, 2019)
Technology Management Maturity Assessment Model (TM-MAM)	The TM-MAM was developed as a technology management tool in hospitals. The TM-MAM assesses the maturity of a health organisation's technology management structures using five maturity levels. The maturity of five domains is assessed in the model:	(Shaygan and Daim, 2019)

Table continues on next page

Table continued from previous page

Maturity Model Title	Description	Maturity model's Reference
	(i) Technology, (ii) Social, (iii) Organisational, (iv) Regulatory, and (v) Financial (Shaygan and Daim, 2019).	
Telemedicine maturity model	In this study, Occelli and Scelfo (2020) use the telemedicine maturity model Van Dyk and Schutte (2013) developed to assess the maturity of the Piedmont Region in Italy to transition to digital healthcare. The domains assessed in the maturity model are (i) governance, (ii) workflow, (iii) users, (iv) financial resources, and (v) technology (Occelli and Scelfo, 2020).	(Occelli and Scelfo, 2020)
National Health Service (NHS) maturity model	The NHS maturity model is a self-assessment tool that enables users to identify areas for improvement to enhance knowledge use in the health organisation (Day and Goswami, 2020). The maturity model is assessed over nine levels of maturity and nine domains: (i) strategic approach, (ii) leadership, (iii) learning organisation, (iv) networking, (v) measuring value, (vi) knowledge capture and re-application, (vii) innovation, (viii) technology for collaboration, and (ix) applying efficiencies to existing practices (Day and Goswami, 2020; National Health Service, 2020).	(Day and Goswami, 2020)
Research Utilisation Maturity Matrix (RUMM)	The RUMM was developed to support knowledge translation for disaster risk reduction (Owen, Krusel and Bethune, 2020). The RUMM consists of five domains: (i) people and culture, (ii) communication and engagement, (iii) resources, (iv) governance, and (v) research outputs (Owen, Krusel and Bethune, 2020). Knowledge translation is measured across four maturity levels from level 1: basic to level 4: leading.	(Owen, Krusel and Bethune, 2020)
Multi-disciplinary Teams' Maturity Matrix	Evans *et al.* (2019) developed a self-assessment tool to monitor the performance of multi-disciplinary teams to improve performance in cancer care. The model consists of five domains: (i) governance and leadership, (ii) meeting logistics, (iii) linkages, (iv) data, and (v) human resources and infrastructure (Evans *et al.*, 2019). The domains are assessed according to five levels of maturity from level 1: basic to level 5: advanced (Evans *et al.*, 2019).	(Evans *et al.*, 2019)

None of the maturity models described in Table 5.6 address FR3 or DR2. These maturity models are not tailored to the LMIC context and, thus, do not apply to a broad range of LMICs (DR2) and do not enable the description of the nuances present in an LMIC context (FR3). Furthermore, the maturity models do not enable a holistic or multi-dimensional assessment of a health innovation landscape (DR3, FR2) and do not apply to a broad range of evidence-based innovations (DR1). The identified maturity models either focus on a specific aspect of the health innovation landscape (e.g., a health facility, organisation, knowledge, region) or a specific innovation (e.g., telemedicine, risk reduction, integrated care, electronic records or mHealth).

The descriptive reviews in Sections 5.2.2.1 and 5.2.2.2 show that a wide range of health and innovation maturity models exist; however, Section 5.2.2.3 emphasises that no maturity model addresses the aim and objectives of this study or that spans the main themes of the study (see Figure 5.3). Even when expanding the search's scope, the returned (Table 5.6) are not appropriate for the study's aim, which calls for an approach to *evaluate health innovation systems and their capability to implement evidence-based innovations in LMICs successfully and sustainably*.

While none of the maturity models identified in Table 5.6 meets all the requirement specifications, they highlight that the maturity model approach is appropriate to achieve the study's aim. Maturity models enable the description of an evolutionary improvement process and can be easily adapted

to address different requirement specifications. Having confirmed that no maturity model exists, a new maturity model will be developed to meet the requirement specifications; in the following sub-section, the existing maturity model types are considered.

5.2.3 Types of Maturity Models: What Type Should Be Developed?

Maturity models can be traced back to the quality management field. An early model assessing maturity is Crosby's 1979 Quality Management Maturity Grid (Fraser, Moultrie and Gregory, 2002). However, maturity models gained popularity after the development of the CMM in the 1980s (Poeppelbuss *et al.*, 2011). The CMM defines the vital elements necessary for a successful software process (Paulk *et al.*, 1993). The CMM describes the maturity of software processes using five levels: (i) initial, (ii) repeatable, (iii) defined, (iv) managed, and (v) optimised (Fraser, Moultrie and Gregory, 2002). Since the CMM was developed, numerous maturity models have been developed using the CMM structure; these models span a broad range of sectors and domains (De Bruin *et al.*, 2005; Poeppelbuss *et al.*, 2011).

A maturity model can be categorised as descriptive, prescriptive or comparative (De Bruin *et al.*, 2005). However, a maturity model is not necessarily confined to one distinct state but progresses through these states, depending on its lifecycle phase (De Bruin *et al.*, 2005). Initially, the maturity model will be descriptive, allowing the user to understand the as-is state. The maturity model can then be developed to the prescriptive state, where the user can prescribe improvements. Lastly, the maturity model can be evolved to be used comparatively. Here, a sufficient amount of maturity model uses must have been completed for it to be used as a benchmarking tool (De Bruin *et al.*, 2005).

There are different methods of structuring a maturity model. The most rudimentary structure is one-dimensional, where a questionnaire is combined with the Likert scale to determine the degree of maturity of a dimension (Triegaardt, 2013). A dimension can be defined as a group of related activities or items that work together to achieve the desired goal (Paulk *et al.*, 1993). The maturity grid is another method of structuring a maturity model; the grid uses descriptive text to assess different system dimensions (Triegaardt, 2013). The third method of structuring a maturity model is using the CMM, the most formalised of the three structures (Triegaardt, 2013). CMMs are an evolution of the maturity grid; a CMM defines each maturity level using a set of cumulative capabilities (Fraser, Moultrie and Gregory, 2002; Triegaardt, 2013).

A capability can be either tangible or intangible; capabilities are specific to the process and domain being assessed (Srai, Alinaghian and Kirkwood, 2013). Capabilities result from the complex interactions between dimensions (Srai, Alinaghian and Kirkwood, 2013). CMMs can be divided into staged fixed-level and continuous fixed-level maturity models. In a staged fixed-level maturity model, each of the capabilities in a level for all the process areas or domains needs to be completed to move to the next maturity level (Fraser, Moultrie and Gregory, 2002). For the continuous fixed-level maturity model, capabilities in one process area or domain can be improved to move to the next maturity level in that process area or domain; thus, the maturity levels of the different process areas or domains do not all have to be identical (Fraser, Moultrie and Gregory, 2002).

The type of maturity model that will be developed in this study is a CMM. The CMM was chosen because it is the most formalised maturity model approach. Furthermore, the developed maturity model would be classified as a continuous fixed-level maturity model. The continuous representation allows the assessor to decide what improvement sequence best meets the assessed system's needs

(CMMI Product Team, 2002); this is particularly important in the health system context, which is complex and dynamic. With the continuous approach, different process areas or domains can be at different maturity levels (Fraser, Moultrie and Gregory, 2002). This is a necessary feature when assessing the health innovation system because, while the various process areas are interrelated and influence one another, it is likely that they will be at differing maturity levels. It is also possible to improve the maturity of one health innovation dimension without improving another; this is another feature of the continuous fixed-level maturity model. The next chapter will consider the process followed to develop a continuous fixed-level CMM.

5.3 CHAPTER 5: CONCLUSION

In this chapter, requirement specifications were defined using the literature reviews of Chapter 1, Chapter 3 and Chapter 4. Maturity models were identified as the structure used to develop a research solution that meets the requirement specifications. The existing studies within the health innovation maturity model landscape were explored, and the results of this exploration again emphasised the gap and the need to develop a novel maturity model. In the next chapter the maturity model development process will be described and followed to develop the HII-MM.

Chapter 6 The LMIC Health Innovation Implementation Maturity Model

The LMIC Health Innovation Implementation Maturity Model (HII-MM) is developed in this chapter. The steps necessary to develop a maturity model are outlined. First, planning is done around the maturity model; then, the maturity model is populated using the research carried out from Chapter 2 through to Chapter 5, resulting in the preliminary maturity model. In the third step, the preliminary maturity model is iteratively refined using various evaluation techniques. The detailed evaluation processes are presented in Chapter 8 (verification) and Chapter 9 (validation). Once the relevant refinements have been incorporated into the preliminary maturity model, the final HII-MM is formed and presented. For brevity and to avoid repeating the maturity model, only the final maturity model is presented in this chapter, and the preliminary maturity model is presented in Appendix F.

Chapter 6 Outline:

6.1 MATURITY MODEL DEVELOPMENT METHODOLOGY

The process followed to develop the HII-MM is described in Chapter 2, Section 2.3.2. An overview of the maturity model development process in the context of this chapter is shown in Figure 6.1.

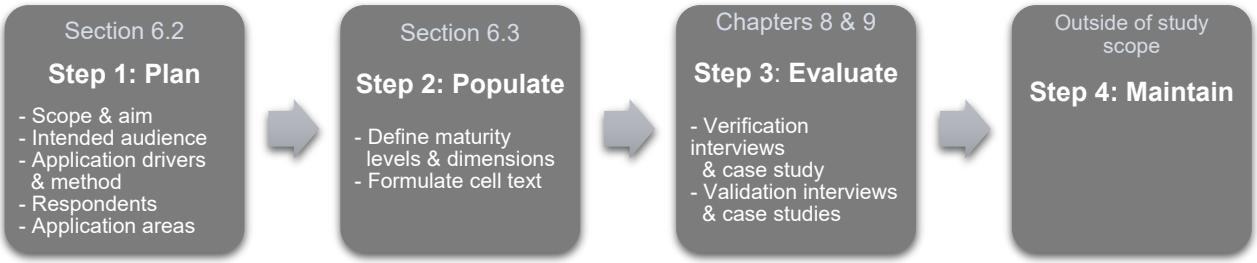


Figure 6.1: Maturity model development process adapted from De Bruin et al. (2005) and Maier, Moultrie and Clarkson (2012)

6.2 MATURITY MODEL DEVELOPMENT STEP 1: PLAN

During the planning step, the maturity model's scope and aim are defined by using the design restrictions (Table 5.4) and the boundary conditions (Table 5.4); in addition, the intended audience and respondents are specified; and the application methods and drivers are specified, using the user requirements (Table 5.2). The scope and aim of the maturity model are described in Section 6.2.1; thereafter, the maturity model's application methods and application drivers are described in Section 6.2.2, and the intended audience and respondents are described in Section 6.2.3.

6.2.1 Aim and Scope

The aim of the maturity model, which correlates to the aim of the study as described in Chapter 1, is the ability to evaluate health innovation systems and their capability to successfully and sustainably implement evidence-based innovations in LMICs. The maturity model should facilitate the assessment of all aspects of an LMIC health system, define the system's current implementation maturity, and provide potential improvement or maturation paths. The scope of the maturity model is defined using the design restrictions and boundary conditions described in Chapter 5, Table 5.3 and Table 5.4, respectively. The scope of the maturity model thus includes:

i. The maturity model must apply to a broad range of evidence-based health innovations;
ii. The maturity model must be relevant to LMIC contexts;
iii. The maturity model must facilitate a systems-level analysis of a health innovation system;
iv. The maturity model must provide a comprehensive assessment of the facilitators and barriers during the implementation process;
v. The maturity model should be able to be applied ethically, conforming to relevant international health and innovation system regulations; and
vi. The maturity model should be operable in different settings, including digital and paper-based methods.

Within a specific LMIC health system, there might be different funding structures (for example, in South Africa, there are publicly funded and privately funded health systems). These fall within the scope of the maturity model. To ensure that there are no ambiguities or misunderstandings of the maturity model's defined aim and scope, it is of value to define the terms "implementation", "sustainability", and "LMIC" for the context of this study:

i. Implementation is *"the use of strategies to adopt and integrate"* evidence-based health innovations in a specific context (Proctor, Powell and McGinnis, 2017, p.1);
ii. Sustainability is the ability of the maturity model to continue over an extended period (Cambridge Learner's Dictionary, 2019); sustainable implementation can be described as the extent to which the innovation can continue over time and be assimilated into the specific context (Iwelunmor *et al.*, 2016); and
iii. LMIC: One method that the World Bank Group uses to classify countries is through income, which is assessed using gross domestic income per capita (The World Bank, 2019). A country can fall into one of four groups: (i) low-income, (ii) lower middle-income, (iii) upper-middle-income, or (iv) high-income. Hence, the acronym LMIC, as used in this study, refers to the low- and middle-income countries as classified by the World Bank. Countries are re-classified yearly (The World Bank, 2019).

After defining the aim and scope of the maturity model, it is necessary to establish the proposed application method and drivers.

6.2.2 Application Method and Drivers

Implementation of innovations is an important mechanism, and it is required if equitable access to healthcare is to be achieved globally (Bergström *et al.*, 2015). The unsuccessful implementation of health innovations frequently occurs (Glasziou *et al.*, 2017), leading to missed opportunities where various aspects of a health system could have been improved (Yamey, 2012). Thus, the drivers for

applying the maturity model include (i) improving the sustainability and success of health innovations, (ii) increasing the number of people who can benefit from an innovation, (iii) addressing health system challenges with appropriate innovations, and more broadly, (iv) contributing to the achievement of the SDG #3: *Good health and well-being* (United Nations, 2015). These drivers were identified in Chapter 1.

The pre-defined user requirements from Chapter 5, Table 5.2, are used to identify the possible application areas of the maturity model. The application areas include, but are not limited to, the following scenarios:

i. In the process of designing an innovation to be implemented in a specific LMIC context: the maturity model can be used to identify and understand the factors that should be considered to support and facilitate the successful and sustainable implementation of the innovation;
ii. Different solutions are being considered to address a specific health system challenge: the maturity model can be used to benchmark innovations against one another, enabling the identification of the most suitable innovation for the health system;
iii. A particular innovation is being considered for implementation in a health system: the maturity model can be used to benchmark potential implementation strategies against one another to identify the most suitable strategy;
iv. An innovation is being considered for implementation: the maturity model can be used to identify potential barriers to the successful and sustainable implementation of the innovation by identifying gaps in the system or the innovation;
v. An implementation process is being planned or carried out: the maturity model can be used to guide scale-up, develop sustainability strategies, or inform change and guide improvement initiatives of the innovation, implementation strategy, or health innovation system; and
vi. The implementation of an innovation was unsuccessful: the maturity model can be used to understand what went wrong by identifying areas for improvement in subsequent implementation processes.

The maturity model should be applicable and usable as a self-assessment tool for a person involved with the innovation, the implementation process, or an LMIC health innovation system. This could include persons developing innovations, implementing innovations, or addressing health system challenges. In addition to the beforementioned direct stakeholders, the maturity model should be usable by a third-party consultant, who is not necessarily a direct stakeholder in the health innovation system. The assessment method must include various data sources to collect the information necessary to complete the maturity assessment. A range of data sources will enable greater accuracy and reduce bias in respect of the person using the maturity model. Relevant data sources that could be used during the maturity assessment include, but are not limited to, (i) policy documents, (ii) population census data, (iii) peer-reviewed journal articles, (iv) workshops, (v) interviews with different stakeholders (including the community, health workers, policymakers, project managers, the innovation company etc.), and (vi) surveys. The results obtained from the maturity assessment should be analysed, synthesised, and presented to the relevant stakeholders. Dissemination of results is necessary to encourage feedback, improve the understanding of the results and develop/ensure buy-in of the proposed improvement initiatives.

6.2.3 Intended Audience and Maturity Model Respondents

Maturity models have two audience types: (i) the internal stakeholders who are involved in the application of the maturity model and (ii) the external stakeholders who are concerned with the results produced by the maturity assessment (Van Dyk, 2013). The intended audience of the maturity model developed in this study may include any of the health innovation system stakeholders described in Chapter 3, Section 3.4.1, i.e., health system regulators, providers, suppliers, payers and patients. The intended audience will vary, depending on the application areas and the drivers of conducting a maturity assessment (see Section 6.2.2).

When applying the maturity model, potential respondents[9] are the relevant stakeholders who can provide insight into the current health implementation landscape and who have knowledge of the innovation being implemented. The respondents could include health workers, policymakers, community members, members of the innovation company, or any other knowledgeable stakeholder. As the maturity model is intended for a wide audience, it is important that UR1, from Table 5.2, Chapter 5, is upheld. The maturity model must thus be user-friendly, with clear instructions guiding its use, and contain definitions for all key terms to ensure accessibility while maintaining the complexity necessary to assess implementation in a health innovation system.

Having completed Step 1 of the maturity model development process, in the following sub-section, how the maturity model was populated is described as per Step 2 of the development process (refer to Figure 6.1).

6.3 MATURITY MODEL DEVELOPMENT STEP 2: POPULATE

This section presents the population of the maturity model. The goal of the population phase is to determine what needs to be measured (De Bruin *et al.*, 2005). The maturity dimensions were defined in this phase, and the maturity model's text was formulated (Maier, Moultrie and Clarkson, 2012). The aim and scope of the maturity model defined in Section 6.2.1, with the functional requirements of Table 5.1, Chapter 5, were used to populate the maturity model,. As stated in the previous section, the maturity model aims to assess the implementation capabilities[10] of an evidence-based health innovation in an LMIC health system. Three maturity dimensions[11], inspired by the Innovation Capability Maturity Model developed by Essmann (2009), were defined to populate the maturity model.

The first dimension of the maturity model, derived from FR2 and FR3 (refer to Table 5.1), is *health system levels*; the maturity model needs to accommodate a system thinking approach and be applicable to an LMIC health system. The second dimension, derived from FR1 and FR4 (refer to Table 5.1), is *implementation domains*; the implementation domains comprise the concepts necessary to describe an LMIC health innovation implementation landscape. The third dimension is

[9] Maturity model respondents are the stakeholders with whom interviews or workshops are conducted to obtain the data necessary to complete the maturity assessment.
[10] As described in Chapter 5, a capability can either be a tangible or intangible concept; capabilities are specific to the process being assessed (Srai, Alinaghian and Kirkwood, 2013); capabilities result from the complex interactions between dimensions (Srai, Alinaghian and Kirkwood, 2013).
[11] As described in Chapter 5, a dimension is a group of related activities or items.

the *maturity levels*; this dimension was derived from FR4 (refer to Table 5.1) and Section 5.2.3, in which maturity model structures are described. Maturity levels are a standard part of a maturity model, enabling the assessment of a health innovation system's capability to implement innovations. These three dimensions are described in detail in Sections 6.3.1 to 6.3.3.

6.3.1 Dimension 1: Health System Levels

It is necessary to describe the health system so that it can be adapted for different health systems to ensure that the maturity model applies to and can describe all LMIC health systems[12], as per FR3 (Table 5.1). The method selected for this differentiation is levels of analysis. Levels of analysis is a phrase originating in sociology; it is used to define a distinct unit being analysed (Blalock, 1979). The levels of analysis method were chosen because it supports the systems thinking perspective: it does not restrict information collection to a single level. It aids with the identification of system-level dynamics that influence outcomes (Berg, 2022).

There are three different levels of analysis: (i) micro, (ii) meso, and (iii) macro (Serpa and Ferreira, 2019). The health system levels of analysis are presented in Figure 6.2. It is important to note that the different health system levels influence each other (Bazos *et al.*, 2015). The micro-system exists and functions within the meso-system. The meso-system exists and functions within the macro-system (Bazos *et al.*, 2015). Figure 6.2 shows that the different health system levels should not be considered isolated entities; even if an innovation is being implemented at the micro-provider level, the micro-community, meso- and macro-levels will likely influence the implementation process. While this study specifically focuses on LMIC health systems, describing a health system using levels of analysis allows for a great deal of flexibility and generalisability, which would allow it to be applied in HICs.

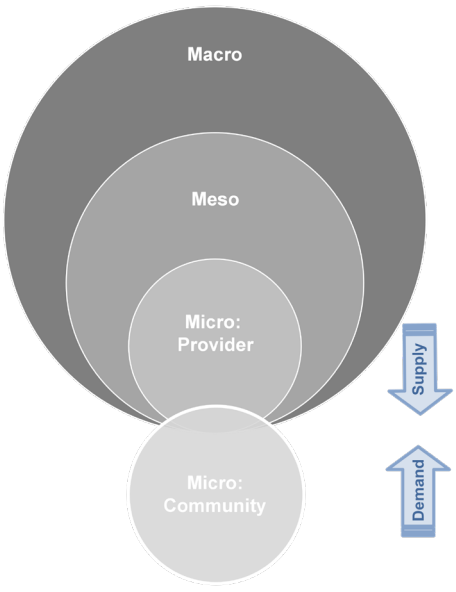


Figure 6.2: Health system levels adapted from Bazos et al. (2015)

[12] As described in Chapter 3, health systems are "*all the activities whose primary purpose is to promote, restore or maintain health*" (Musgrove *et al.*, 2000). This includes the resources, people, institutions and organisations that aim to improve health (World Health Organization, 2010b).

The micro-health system level is split into two components: (i) provider and (ii) community level. The community level was included because it is a crucial part of the health system. The community was repeatedly identified as a key facilitator or barrier to implementation during the systematic literature review, which is presented in Chapter 4. As depicted by the arrows in Figure 6.2, the two micro-levels interact; the demand for healthcare services comes from the community, and the providers supply the services to the community, facilitated by the meso- and macro-health system levels. In Table 6.1, each health system level is defined based on the definitions of the levels of analysis of systems (Serpa and Ferreira, 2019).

Table 6.1: Description of the health system levels

Health system level	Description
Micro: Community	The micro-community level includes the members of the population who are beneficiaries of health services. More specifically, it refers to members of the population who are beneficiaries (this could be directly or indirectly, e.g., family members) of the services resulting from implementing an innovation.
Micro: Provider	The micro-provider level refers to the providers tasked with using the innovation. Providers are not limited to the health professionals within a healthcare facility; they also include community health workers (CHWs) [13], lay councillors, etc.
Meso	The meso-level is any "*government entity below the national level, regardless of the political, financial and administrative design of the country*" (Rohrer, 2016, p.1). The meso-level includes (i) parastatals, states (e.g., in Nigeria and India), (ii) provinces (e.g., in South Africa), (iii) regions (e.g., in Mali and Tanzania), and (iv) districts (the local health system) (Rohrer, 2016).
Macro	The macro-level is the first tier of a country's government system (Rohrer, 2016). The decisions made at the meso-level include the planning, delivery, evaluation and regulation of health services (Boateng, 2013). However, there is flexibility for the macro-level to be an entity below the country's first tier but above the meso-level or for the macro-level to be above the country's first tier, e.g., regional.

6.3.2 Dimension 2: Implementation Domains

The detailed literature reviews conducted in Chapter 3 and Chapter 4 are utilised to ensure that the maturity model contributes to an understanding of the characteristics and properties of an implementation process, encompassing the barriers and enablers to innovation implementation in LMIC health systems (as per the functional requirements, Table 5.1). The conceptual literature review on health innovation systems (Chapter 3), and the systematic literature review on the barriers and facilitators to innovation implementation in LMIC health systems (Chapter 4), form the basis for defining the implementation domains dimension. The process followed to populate the implementation domains is shown in Figure 6.3. The Conceptual Health Innovation System framework, presented in Chapter 3, was used to determine the overarching implementation domains. The results from the systematic literature review, which identified the facilitators and barriers to health innovation implementation in LMICs, conducted in Chapter 4, were used to determine the implementation sub-domains.

[13] CHWs are frontline health providers who receive training over a short period (fewer than three years). CHWs can provide culturally suitable health services, as they are usually from the community they serve (Olaniran *et al.*, 2017).

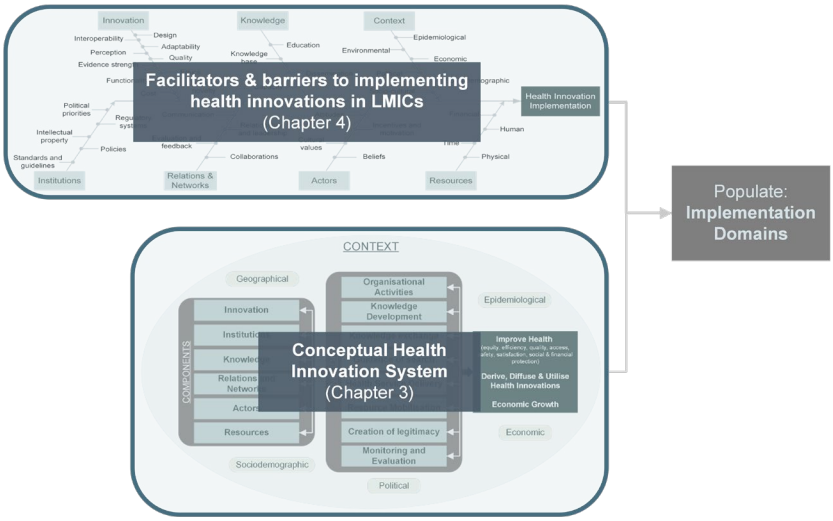


Figure 6.3: Process of populating the implementation domains dimension

The overarching implementation domains identified in Chapter 3 are (i) innovation, (ii) institutions, (iii) knowledge, (iv) relations & networks, (v) actors, (vi) resources, and (vii) context. In Chapter 4, Section 4.3.4, systematic literature review results were categorised into these domains. Within the domains, sub-domains were formed by grouping equivalent implementation barriers and facilitators (refer to Figure 4.8 in Chapter 4 for the sub-domains identified from the systematic literature results). Some sub-domains identified during the systematic literature review were merged while the preliminary maturity model was being developed. This was done to simplify the domains and to avoid duplication of the sub-domains. The sub-domains that were merged, and the specific reasons for merging these sub-domains, are described in Table 6.2.

Table 6.2: Adjustments made to the implementation domain sub-components identified in the systematic literature review performed in Chapter 4

Sub-domains merged	Reason for merging the sub-domains
Innovation sub-domains: *interoperability* and *adaptability* were merged.	The interoperability of an innovation and its adaptability are closely associated. An innovation may not be interoperable within a specific context in its current form. However, when adapted, it could become interoperable.
Innovation sub-domains: *design* and *quality* were merged.	How an innovation is designed will directly influence the innovation's quality.
Institutions sub-domains: *regulatory system* and *intellectual property* were merged.	Intellectual property is a part of the regulatory system.
Relations & networks sub-domains: *evaluation & feedback* and *communication* were merged.	Communication is a vital part of evaluation and feedback. Communication is required to evaluate or give feedback.
Actors sub-domains: *attitudes* and *beliefs* were merged.	The beliefs that an actor has results in specific attitudes.
Context sub-domain: *epidemiology* was merged with the institutions sub-domain: *political priorities.*	The epidemiology of a specific context affects the competing disease priorities, which in turn influence political priorities.
Context sub-domain: *economic*, was merged with the resources sub-domain: *financial.*	The economic context is described by the macro-level financial resources domain.
Context sub-domain: *socio-demographic*, was merged with the innovation sub-domain: *interoperability.*	One of the aspects that influences an innovation's interoperability is the socio-demographics of the actors involved during implementation.

Further refinements were made to the implementation domains and the corresponding sub-domains during the verification phase of the evaluation process; these are detailed in Chapter 8. The resulting implementation domains and corresponding sub-domains that were included in the final maturity model are presented in Table 6.3. The implementation domains provide a holistic view of the facilitators and barriers to implementing an innovation in an LMIC context.

Table 6.3: Implementation domain descriptions and the corresponding sub-domains

Domain	Definition of domain	Sub-domains
Innovation	In the innovation domain, the actual evidence-based health innovation is assessed. A health innovation, which is also referred to as a health intervention, is any new "*concept, idea, service, process, or product"* that aims to improve some aspect of health, including health education, treatments, prevention, diagnosis, outreach or research (Omachonu and Einspruch, 2010, p.5).	i) Design & functionality ii) Supporting Evidence iii) Ethics & equity
Resources	The resources domain refers to the assets present within the health innovation system. Resources are the supply of something that a country has and can use (Oxford Dictionaries, 2019f).	i) Infrastructure, services & physical resources ii) Human resources iii) Financial resources
Institutions	The institutions domain refers to the rules, laws and practices that shape interactions within the health innovation landscape (Hodgson, 2006). Institutions offer structure and insights into how actors behave in the system (Soete, Verspagen and ter Weel, 2010). The roles of institutions are to guide and oversee the health system and to protect the population that uses and is part of the health system (World Health Organization, 2007a).	i) Laws & regulations ii) Policies iii) Standards & guidelines iv) Institutions & priorities
Relations & networks	The relations & networks domain considers the links between groups of actors within and between different health system levels. Relations describe how things are connected; a network is a group of interconnected people or things. Health innovation networks and relations link groups of actors at the national, regional or international level (Chataway *et al.*, 2009).	i) Relationship dynamics ii) Collaborations iii) Evaluation networks
Actors	The actors domain refers to the sociology of the people participating in health system actions or processes. Actors are any people who participate in health system actions or processes. Healthcare actors include (i) patients, (ii) providers, (iii) payers, (iv) suppliers and (v) regulators (Bessant, Kunne and Möslein, 2012). The actors in the health innovation system create, diffuse and use the innovations (Hekkert *et al.*, 2011).	i) Culture ii) Motivations iii) Beliefs & attitudes
Knowledge	The knowledge domain refers to the information and understanding actors have of the various aspects of the implementation process. Knowledge can be defined as the information and understanding of a subject area (Collins English Dictionary, 2019c).	i) Dissemination & diffusion ii) Knowledge base & capacity iii) Education & training

6.3.3 Dimension 3: Maturity Levels

The assessment measure used in maturity models is maturity levels. Maturity levels enable the understanding of the capability of a system to implement an innovation, as specified in FR4 (Table

5.1). The maturity levels used are structured according to the CMM[14]; these are described in Table 6.4: Level 0 represents the lowest, and least optimal level of maturity, while Level 5 represents the highest, and most optimal level of maturity.

Table 6.4: Generic descriptions of maturity levels (CMMI Product Team, 2002)

Maturity level	Description
Level 0: None	Does not exist.
Level 1: Initial	The processes are ad-hoc or chaotic, and any success is the result of individuals.
Level 2: Repeatable	The processes are managed, measured and controlled.
Level 3: Defined	The processes are established and understood.
Level 4: Managed	The processes are quantitatively managed, and they are predictable.
Level 5: Optimising	The focus is on optimising and continuously improving the processes.

The maturity levels are an effective method for evaluating qualitative studies (Kohlegger, Maier and Thalmann, 2009), which is appropriate for the qualitative nature of assessing implementation in a health innovation system. Maturity levels are cumulative; therefore, to progress to the next level, the characteristics of the previous levels must first be met. The generic maturity level descriptions in Table 6.4 were adapted to ensure their applicability to the specific implementation domains (Van Dyk, 2013).

In the next section, the three dimensions, described in Sections 6.3.1 to 6.3.3, are combined to form the final maturity model.

6.4 THE LMIC HEALTH INNOVATION IMPLEMENTATION MATURITY MODEL

The HII-MM is a maturity assessment tool that facilitates the assessment of LMIC health systems. It defines the system's current implementation maturity and provides potential improvement or maturation paths. The HII-MM's aim is to promote and improve the successful and sustainable implementation of evidence-based health innovations into LMIC health systems. The HII-MM comprises the integration of the three dimensions, which were described in Sections 6.3.1 to 6.3.3, (i) health system levels, (ii) implementation domains, and (iii) maturity levels. These dimensions interact with one another to form the three HII-MM planes shown in Figure 6.4.

[14] Refer to Section 5.2.3 in Chapter 5. The CMM is an established model; since it was developed, numerous maturity models have been developed using the CMM structure; these models span a broad range of sectors and domains (De Bruin *et al.*, 2005; Poeppelbuss *et al.*, 2011).

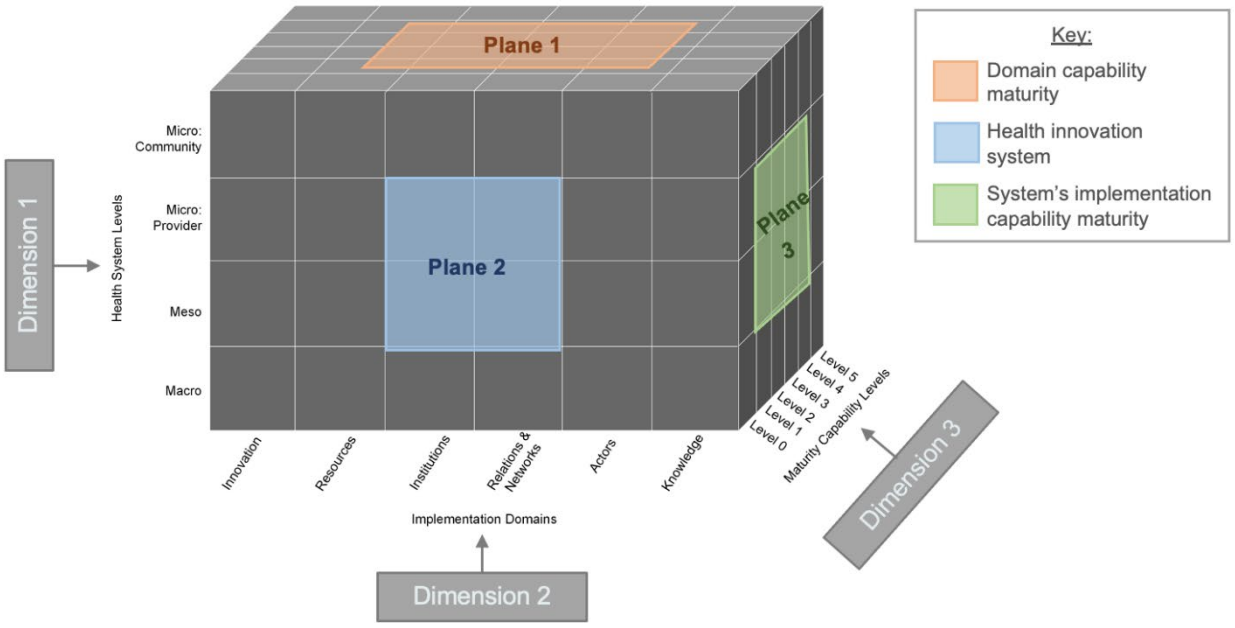


Figure 6.4: Conceptual HII-MM

The following sub-sections will describe the interactions between the dimensions and the resulting three planes of the HII-MM. Section 6.4.1 describes the *implementation domain capability maturity* plane. Section 6.4.2 describes the *health innovation system* plane, and Section 6.4.3 describes the *system's implementation capability maturity* plane.

6.4.1 Plane 1: Implementation Domain Capability Maturity

As shown in Figure 6.5, Plane 1 is formed by integrating two dimensions: (i) the implementation domains and (ii) the maturity levels.

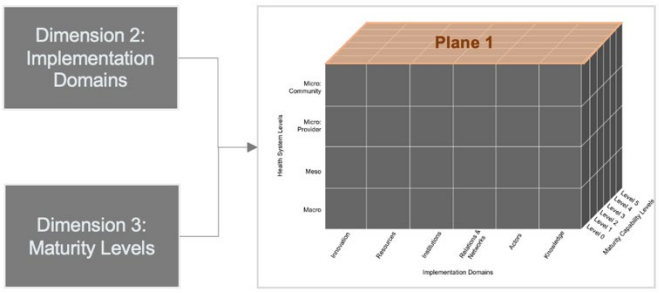


Figure 6.5: Flowchart showing the interactions between the dimensions that result in Plane 1: implementation domain

Maturity levels are statements that enable the understanding of the capability of a system to implement an innovation; the maturity levels outline an evolutionary path for improvement. The maturity model has six implementation domains (i.e., innovation, resources, institutions, actors, relations & networks, and knowledge). The implementation domains provide a holistic view of the 'hard' (technical or tangible metrics, e.g., cost) and 'soft' (non-technical or intangible metrics, e.g., culture) concepts in a health innovation system that may impact an implementation process. The implementation domains are further broken down into sub-domains (refer to Section 6.3.2) to provide a more detailed understanding of the system. In Plane 1, the generic maturity level statements of Table 6.4 are individualised for each implementation sub-domain. The implementation domain-specific capability maturity statements are presented in Appendix G, Section G.1.

6.4.2 Plane 2: Health Innovation System

As shown in Figure 6.6, Plane 2 is formed by integrating two dimensions: (i) health system levels and (ii) implementation domains.

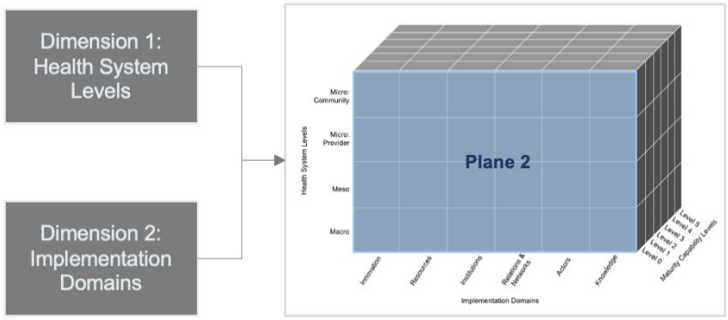


Figure 6.6: Flowchart showing the interactions between the dimensions that result in Plane 2: health innovation system

The implementation domains described the concepts present in a health innovation system. The health system levels dimension describes the four levels of analysis at which a health system can be analysed; these can be adapted to befit different assessment contexts. Plane 2 describes the implementation concepts of an implementation sub-domain specific to the health system levels. The health system levels with the tailored implementation sub-domain descriptions are presented in Appendix G, Section G.2.

6.4.3 Plane 3: System's Implementation Capability Maturity

As shown in Figure 6.7, Plane 3 combines all three dimensions and is formed by integrating Planes 1 and 2. The resulting *system's implementation capability maturity* plane forms the basis for the user interfaces. As depicted in Figure 6.7, Plane 3 consists of multiple user interfaces; each implementation sub-domain has a user interface. Each of the six implementation domains has between three and four sub-domains; in total, there are 19 implementation sub-domains.

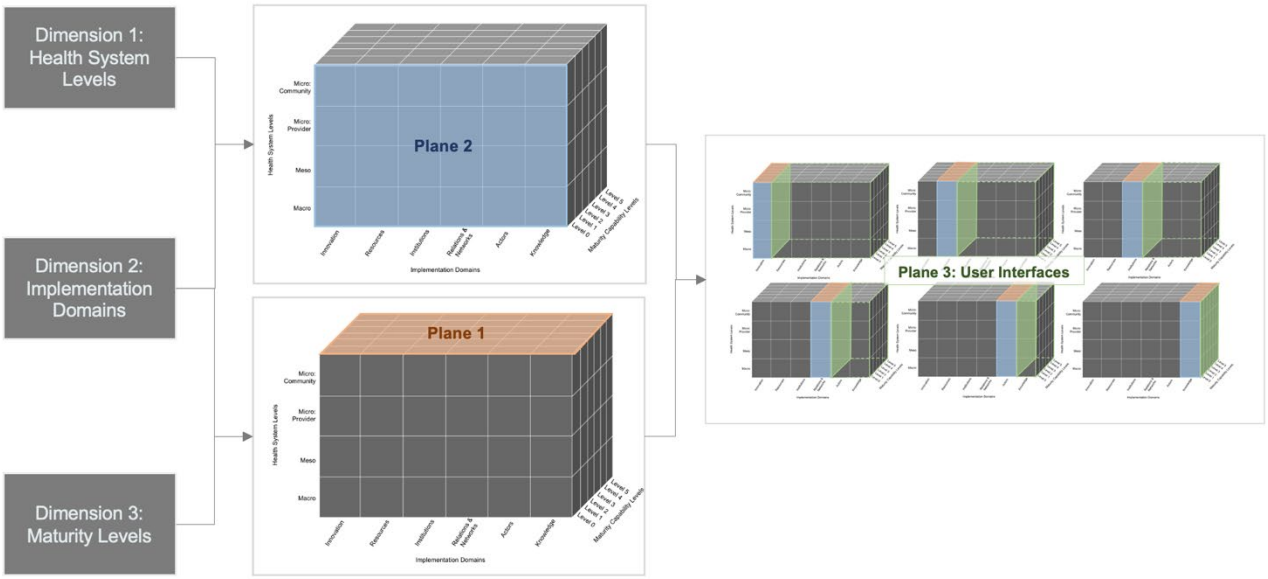


Figure 6.7: Flowchart showing the interactions between the dimensions and planes that result in Plane 3

Figure 6.8 outlines the components of an HII-MM user interface (i.e., Plane 3). A user interface in the context of the HII-MM is a matrix[15]; Planes 1 and 2 form the x and y axes of the matrix, respectively. These planes are leveraged to develop capability maturity statements for each implementation sub-domain. The user interfaces are used during the maturity assessment to determine the maturity levels of each implementation sub-domain at each health system level.

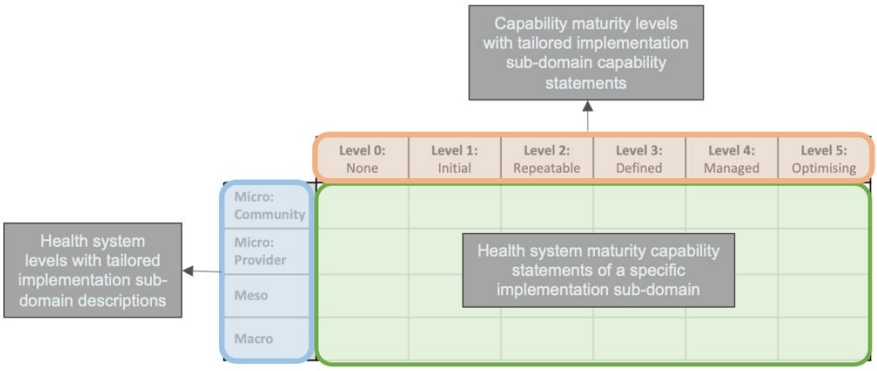


Figure 6.8: Components of the maturity model user interface

Figure 6.9 depicts the user interface matrix for the innovation sub-domain: design & functionality. The remaining 18 user interface matrices are presented in Appendix G Section G.3. In the following sub-sections, the user interfaces of each implementation domain are described.

Innovation sub-domain: Design & Functionality		Maturity Capability Levels					
		Level 0: No interoperability, does not function.	**Level 1:** Interoperability and functionality are inconsistent.	**Level 2:** Partially interoperable, adaptability is controlled.	**Level 3:** Interoperable with the system, interoperability and functionality is understood.	**Level 4:** Interoperability and functionality within the system are predictable and managed.	**Level 5:** Ability to continually adapt to ensure optimal functionality and continuous interoperability.
Health System Levels	**Micro: community** Socio-demography of the community. Community's needs / wants.	No socio-demographic interoperability. / Does not address community needs.	Inconsistent interoperability. / Interoperable with a minority of the community.	Partial interoperability with the community. Some adaptations are needed to improve interoperability.	Fully interoperable with the community. Interoperability understood.	Interoperability of the innovation with the community is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the community.
	Micro: provider Existing practices. Socio-demography of providers. Provider's needs / wants.	No socio-demographic interoperability. / Does not address provider needs. / Not interoperable with existing practices.	Inconsistent interoperability with providers. / Only interoperable with a few providers.	Partial interoperability with providers. Some adaptations are needed to improve interoperability.	Fully interoperable with providers. Interoperability understood.	Interoperability of the innovation with providers is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with providers.
	Meso Meso-level conditions, processes or practices. Meso-level needs / wants.	No interoperability with the meso-level. / Does not address meso-level needs.	Inconsistent or poor interoperability with the meso-level conditions, processes, practices or needs.	Partial interoperability with meso-level conditions, processes or practices. Some adaptations are needed to improve interoperability.	Fully interoperable with meso-level. Interoperability understood.	Interoperability of the innovation with the meso-level is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the changing meso-level.
	Macro Macro-level processes or practices. Macro-level needs / wants.	No interoperability with the macro-level. / Does not address macro needs.	Inconsistent or poor interoperability with macro-level processes, practices or needs.	Partial interoperability with macro-level. Some adaptations are needed to improve interoperability.	Fully interoperable with macro-level, interoperability understood.	Interoperability of the innovation with the macro-level is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the changing macro-level.

Figure 6.9: User interface for the innovation sub-domain: design & functionality

[15] A matrix is a group of things that are arranged in a rectangle; matrices are used to measure or solve problems (Cambridge English Dictionary, 2019a)

6.4.3.1 Innovation Domain User Interfaces

In the innovation domain, the evidence-based health innovation is assessed. The innovation domain is divided into three sub-domains (i) design & functionality, (ii) supporting evidence, and (iii) ethics & equity, each with a user interface. The location of the innovation user interfaces in the conceptual HII-MM is shown in Figure 6.10.

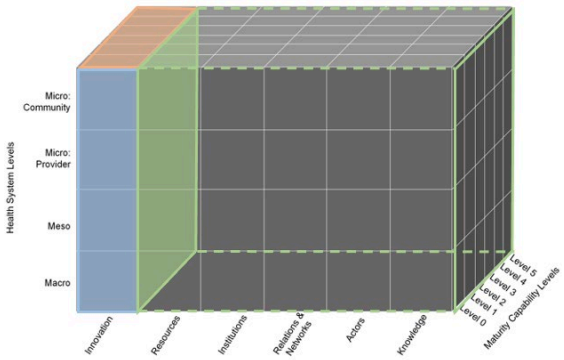


Figure 6.10: Location of the innovation user interfaces on the HII-MM

The innovation user interfaces are:

i. Design & functionality: the features and functions of the innovation to determine its interoperability with the setting into which it is being implemented and with the needs present in the different health system levels;
ii. Supporting evidence: the formal and informal evidence that demonstrates the innovation's validity and the benefits associated with implementing the innovation; and
iii. Ethics & equity: the ethical and equity implications of the innovation, its implementation, and the implementation process.

6.4.3.2 Resources Domain User Interfaces

The resources domain refers to the assets present within the health innovation system. The resources domain is divided into three sub-domains, (i) infrastructure, services & physical resources, (ii) human resources, and (iii) financial resources, each of which has a user interface. The location of the resource's user interfaces in the HII-MM is shown in Figure 6.11.

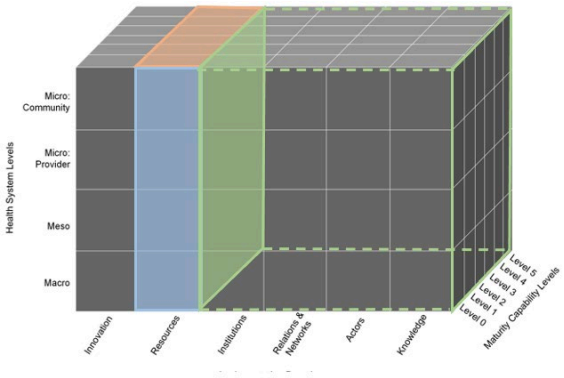


Figure 6.11: Location of the resources user interfaces on the HII-MM

The resources user interfaces are:

i. Infrastructure, services & physical resources: the existing infrastructure, services and physical resources present and available in the health innovation system. This includes information systems, technological infrastructure, pharmaceuticals, health system supplies, health service provision, transport networks, etc.;
ii. Human resources: the presence or absence of certain individuals within the system and during the implementation process; and
iii. Financial resources: any monetary aspects involved in the implementation process.

6.4.3.3 Institutions Domain User Interfaces

The institutions domain refers to the rules, laws and practices that shape interactions within the health innovation landscape. The institutions domain is divided into four sub-domains, (i) laws & regulations, (ii) policies, (iii) standards & guidelines, and (iv) institutions & priorities, each of which has a user interface. The location of the institutions user interfaces in the HII-MM is shown in Figure 6.12.

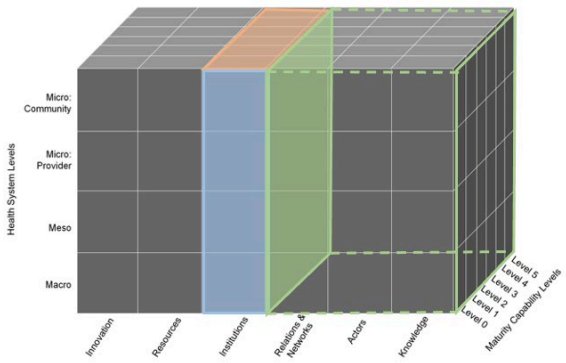


Figure 6.12: Location of the institutions user interfaces on the HII-MM

The institutions user interfaces are:

i. Laws & regulations: the mandatory legislation that governs a system;
ii. Policies: a group of plans and ideas agreed on by an organisation;
iii. Standards & guidelines: any documentation that guides the use of an innovation or that guides different aspects of the implementation process; and
iv. Institutions & priorities: the institutions present and their priorities.

6.4.3.4 Relations & Networks Domain User Interfaces

The relations & networks domain considers the links between groups of actors within and between different health system levels. The relations & networks domain is divided into three sub-domains, (i) relationship dynamics, (ii) collaborations, and (iii) evaluation networks, each of which has a user interface. The location of the relations & networks user interfaces in the HII-MM are shown in Figure 6.13.

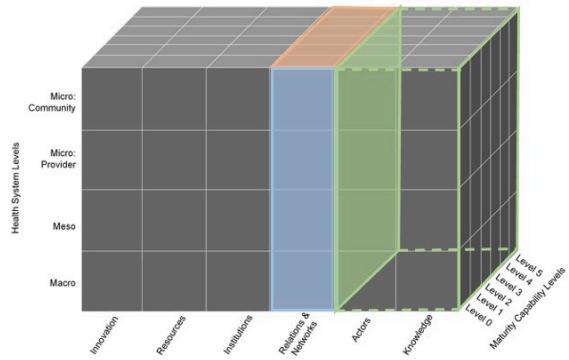


Figure 6.13: Location of the relations & networks user interfaces on the HII-MM

The relations & networks user interfaces are:

v. Relationship dynamics: the relationships and leadership structures present within and between different health system levels;
vi. Collaborations: any joint endeavour between two or more stakeholders; and
vii. Evaluation networks: evaluation, communication, and feedback practices within and between different health system levels.

6.4.3.5 Actors Domain User Interfaces

The actors domain is the sociology of the people participating in the health system's actions or processes. It differs from the human resources sub-domain, as it considers the 'soft' aspects of people, whereas human resources are related to the presence or absence of people. The actors domain is divided into three sub-domains, (i) culture, (ii) motivations, and (iii) beliefs & attitudes, each of which has a user interface. The location of the actor's user interfaces in the HII-MM is shown in Figure 6.14.

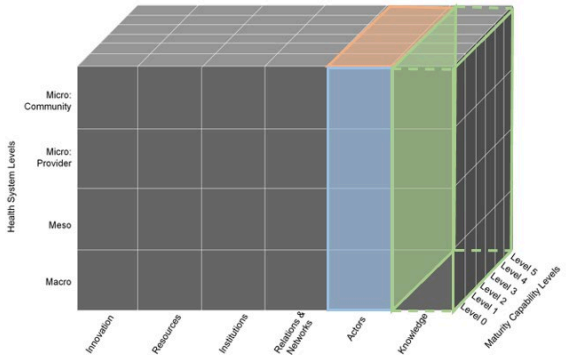


Figure 6.14: Location of the actors user interfaces on the HII-MM

The actors user interfaces are:

i. Culture: the customs, way of life, or social organisation shared between a particular group of people;
ii. Motivations: the actors' motivations are assessed in terms of explicit and indirect incentives and disincentives; and
iii. Beliefs & attitudes: the actors' beliefs that influence their attitudes towards the health system and the innovation and implementation processes. The type of innovation being implemented

influences beliefs & attitudes. The innovation type (categorised according to its degree of novelty and impact) influences the threats posed by and the benefits associated with using the innovation, including perceptions about its complexity, usefulness, or importance.

6.4.3.6 Knowledge Domain User Interfaces

The knowledge domain refers to the information and understanding actors have of the various aspects of the implementation process. The knowledge domain is divided into three sub-domains, (i) dissemination & diffusion, (ii) knowledge base & capacity, and (iii) education & training, each of which has a user interface. The location of the knowledge user interfaces in the HII-MM is shown in Figure 6.15.

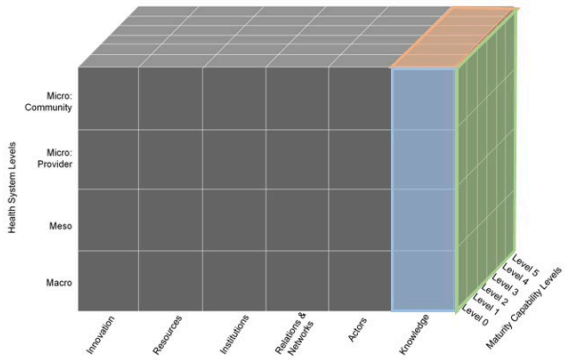


Figure 6.15: Location of the knowledge user interfaces on the HII-MM

The knowledge user interfaces are:

i. Dissemination & diffusion: the active and passive spread of information surrounding the innovation or the implementation process;
ii. Knowledge base & capacity: the knowledge base comprises the expertise and skills that a person has, and knowledge capacity refers to the number of people in an organisation or system who have the necessary knowledge base to use or implement the innovation; and
iii. Education & training: any process that facilitates learning among the actors present; this includes the availability of training for the innovation, mentoring, change management processes, the medical curriculum in the country and health education in a country.

6.5 CHAPTER 6: CONCLUSION

In this chapter, the process followed to develop the HII-MM is described. Two development steps were detailed: (i) plan and (ii) populate. The third development step, (iii) evaluate, will be described in Chapter 8 (verification) and Chapter 9 (validation). During the planning step, the requirement specifications, defined in Chapter 5, were used to define the aim, scope, application method, application drivers, intended audience and respondents of the maturity model. During the population step, the literature studies completed in Chapter 3 through to Chapter 5 were leveraged to construct the preliminary maturity model. Lastly, the final maturity model, the HII-MM, is presented in this chapter. In the next chapter, the operationalisation of the HII-MM will be described.

Chapter 7 Operationalising the LMIC Health Innovation Implementation Maturity Model

In this chapter, the operationalisation of the HII-MM is presented. The HII-MM is operationalised as a workbook in Microsoft Excel. The workbook comprises four introductory worksheets (described in Section 7.1) and one worksheet outlining the instructions that should be followed for the assessment process (described in Section 7.2). These 32 worksheets that are considered user interfaces, of which 20 allow for user inputs (described in Sections 7.3 and 7.4) and three concluding worksheets (described in Section 7.5). The operationalised HII-MM is presented in Appendix H. In the final section of this chapter, Section 7.6, the operational implications of the HII-MM are discussed.

Chapter 7 Outline:

7.1 HII-MM: INTRODUCTORY SECTIONS

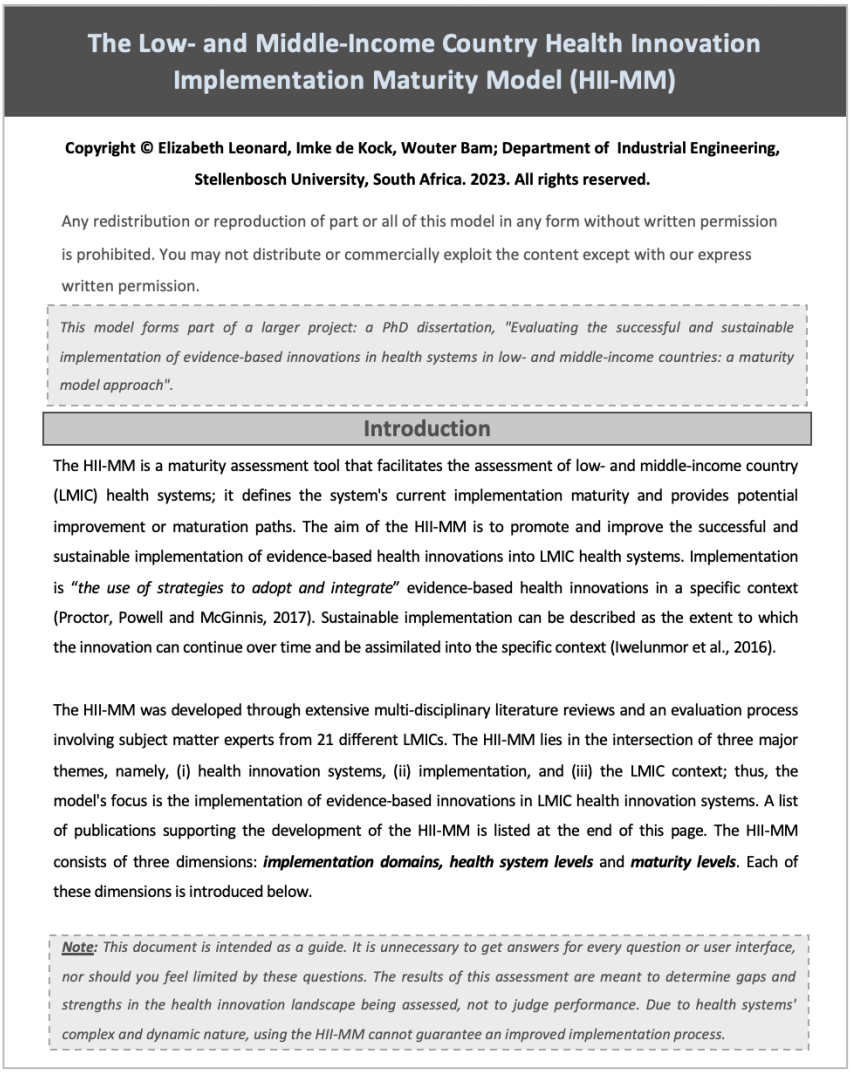
The Microsoft Excel workbook begins with an introduction to the HII-MM. They consist of (i) the landing page, (ii) an overview page, (iii) a frequently asked questions (FAQ) page, and (iv) the index page.

The landing page serves as an introduction to the maturity model as a whole. Figure 7.1 shows the top part of the HII-MM landing page. The HII-MM's intended purpose is set out, and the development process is summarised on the landing page. Additionally, the landing page includes a description of the three dimensions of the maturity model:

i. The implementation domains are described as the broad concepts identified as facilitators or barriers when implementing an evidence-based innovation within an LMIC context. The domains are interrelated and can be assessed in any order. It is advised that all sub-domains are considered during the assessment; however, there is a not applicable (N/A) option that can be used if a particular section is irrelevant.
ii. The health system levels portray the health system that is being assessed. The health system levels interact with and influence one another and will have differing degrees of influence on the implementation process and the implementation domains. While it is advised to consider each health system level to promote a system thinking perspective, there will be assessment scenarios where one or more health system levels are not applicable. For these, the N/A option should be used.

iii. The maturity levels are statements that enable the understanding of the capability of a system to implement an innovation. Lower maturity levels indicate a higher chance that the innovation implementation process will be unsuccessful. In comparison, higher maturity levels indicate a higher chance of the successful and sustainable implementation of the innovation. Maturity Level 0 represents the lowest, least optimal maturity level and Level 5 represents the highest, most optimal level of maturity. In continuous fixed-level maturity models, which the HII-MM is, the maturity levels are cumulative; therefore, to progress to the next level, the characteristics of the previous levels must first be met (Fraser, Moultrie and Gregory, 2002).

Lastly, the landing page lists the publications supporting the development of the HII-MM.



The Low- and Middle-Income Country Health Innovation Implementation Maturity Model (HII-MM)

This model forms part of a larger project: a PhD dissertation, "Evaluating the successful and sustainable implementation of evidence-based innovations in health systems in low- and middle-income countries: a maturity model approach".

Introduction

The HII-MM is a maturity assessment tool that facilitates the assessment of low- and middle-income country (LMIC) health systems; it defines the system's current implementation maturity and provides potential improvement or maturation paths. The aim of the HII-MM is to promote and improve the successful and sustainable implementation of evidence-based health innovations into LMIC health systems. Implementation is "*the use of strategies to adopt and integrate*" evidence-based health innovations in a specific context (Proctor, Powell and McGinnis, 2017). Sustainable implementation can be described as the extent to which the innovation can continue over time and be assimilated into the specific context (Iwelunmor et al., 2016).

The HII-MM was developed through extensive multi-disciplinary literature reviews and an evaluation process involving subject matter experts from 21 different LMICs. The HII-MM lies in the intersection of three major themes, namely, (i) health innovation systems, (ii) implementation, and (iii) the LMIC context; thus, the model's focus is the implementation of evidence-based innovations in LMIC health innovation systems. A list of publications supporting the development of the HII-MM is listed at the end of this page. The HII-MM consists of three dimensions: ***implementation domains, health system levels*** and ***maturity levels***. Each of these dimensions is introduced below.

***Note**: This document is intended as a guide. It is unnecessary to get answers for every question or user interface, nor should you feel limited by these questions. The results of this assessment are meant to determine gaps and strengths in the health innovation landscape being assessed, not to judge performance. Due to health systems' complex and dynamic nature, using the HII-MM cannot guarantee an improved implementation process.*

Figure 7.1: Section of the HII-MM landing page; refer to Section H.1 of Appendix H for complete landing page

In Figure 7.2, the overview page is presented. The objective of the overview page is to provide the user with a descriptive explanation of the HII-MM. The FAQ page is the third introductory worksheet. It is structured according to the United Nations Children's Fund (UNICEF) Public Supply Chain Maturity Scorecard (UNICEF, 2014). It provides the user with additional information to improve their understanding of the HII-MM (refer to Section H.2 of Appendix H). The last worksheet in the introductory section is the index page, which contains hyperlinks, enabling the user to navigate through the HII-MM (refer to Section H.3 of Appendix H).

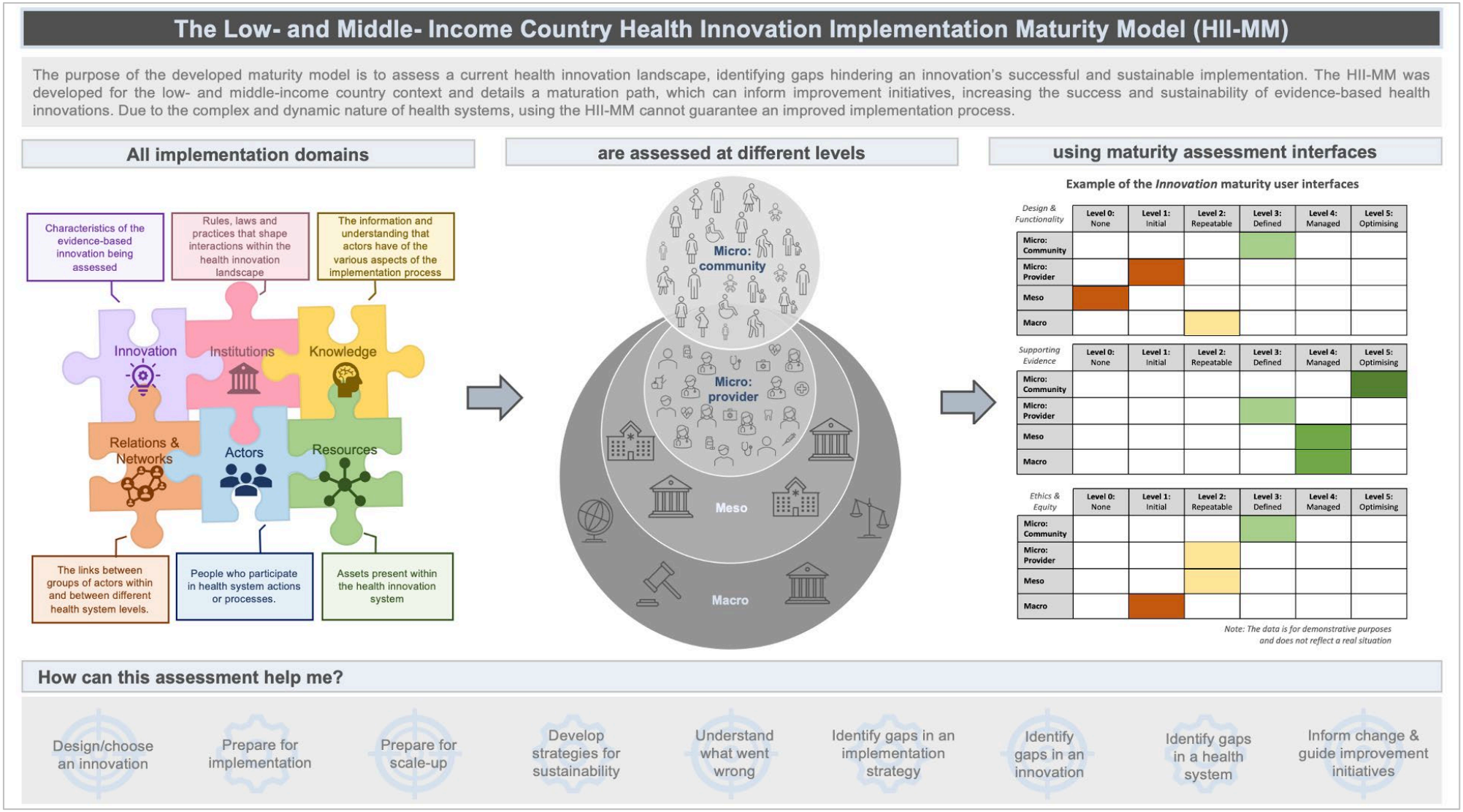


Figure 7.2: HII-MM overview page

The maturity model has been developed to be adaptable to the different phases of an implementation process. The implementation phases used in this maturity model are: (i) searching for, selecting, or designing an innovation, (ii) preparing for implementation, (iii) implementing the innovation, and (iv) sustaining the innovation. The implementation process combines the innovation adoption process described by Tidd and Bessant (2009) and the health-specific implementation process described by Aarons, Hurlburt and Mccue Horwitz (2010). As summarised in Figure 7.2, there are numerous scenarios in which the HII-MM can be used, and these use scenarios are discussed in Table 7.1.

Table 7.1: HII-MM use scenarios

Scenario	Conducting the maturity assessment
Pre-implementation: Design an innovation	i. When using the HII-MM to support the innovation design process, the user should first aim to understand the as-is state of the different health system levels by completing the (i) general, (ii) resources, (iii) institutions, (iv) relations & networks, (v) actors, and (vi) knowledge user interfaces. This ensures that the user develops an in-depth understanding of the setting in which the innovation will be implemented. ii. Next, the innovation user interfaces should be reviewed to ensure that the innovation's design & functionality, supporting evidence, ethics & equity are interoperable with the health system in which it is being implemented. iii. The assessment results should enable the user to effectively design the innovation for the setting into which it will be implemented.
Pre-implementation: Choose or search for an appropriate innovation	i. The HII-MM can be used to choose the most appropriate innovation for a specific health system setting and challenge/gap. First, the potential innovations identified for implementation should be independently assessed using the (i) general and (ii) innovation user interfaces. ii. The user should then assess the as-is state of the health system by completing the (i) resources, (ii) institutions, (iii) relations & networks, (iv) actors, and (v) knowledge user interfaces. iii. The assessment results should enable the user to benchmark the assessed innovations against one another and identify the most suitable innovation for the setting.
Pre-implementation: Prepare for implementation	i. The HII-MM can be used to prepare for the implementation of a specific innovation, highlighting the implementation facilitators and barriers of the innovation and health system. ii. In this scenario, all the user interfaces should be utilised, in any order, to assess the as-is state of the innovation and health system. iii. The maturity assessment results provide insights into which aspects of the innovation and/or health system should be improved before implementation. As well as what supporting interventions/implementation strategies should be considered to ensure a successful and sustainable implementation process (e.g., training, guidelines, information, education and communication material, stakeholder engagements, finance acquisition, etc.).
Inter-implementation: Inform change & guide improvement initiatives or prepare for scale-up	i. The HII-MM can be used inter-implementation to inform change, guide improvement processes or prepare for scale-up. ii. In this scenario, all the user interfaces should be utilised, in any order, to assess the as-is state of the innovation, health system and implementation strategies. The various aspects of different implementation strategies are interspersed in the different user interfaces. iii. The insights gained from the assessment can be used to identify any barriers hindering the successful implementation of the innovation. The results should be used to understand whether, where and what adjustments need to be made to the health system, implementation strategies or innovation.

Table continues on next page

Table continued from previous page

Scenario	Conducting the maturity assessment
Sustainment: Develop sustainability strategies	i. The HII-MM can be used to improve the sustainability of the innovation. ii. In this scenario, all the user interfaces should be utilised, in any order, to assess the as-is state of the innovation, health system and implementation strategies. iii. The insights gained from the assessment can be used to identify any barriers hindering the sustainability of the innovation. The results should be used to understand whether, where and what adjustments need to be made to the health system, implementation strategies or innovation to ensure sustainable implementation.
Post-implementation: Understand what went wrong	i. The HII-MM can be used to understand what went wrong when an innovation or implementation process is unsuccessful. ii. In this scenario, all the user interfaces should be utilised, in any order, to assess the innovation, health system and implementation strategies as experienced during the unsuccessful process. iii. The maturity assessment should provide insights as to why the innovation was unsuccessful and details of which aspects of the innovation and/or the health system would need to be improved, to improve the innovation's success.

7.2 HII-MM: ASSESSMENT PROCESS

The HII-MM instructions page details the steps that should be followed to complete the assessment process. A section of the instructions page is displayed in Figure 7.3 (refer to Section H.4 of Appendix H for the comprehensive set of instructions). In addition to the detailed instructions presented in this worksheet, a discussion around understanding and interpreting maturity levels is provided to assist users in completing the user interfaces and interpreting the assessment results.

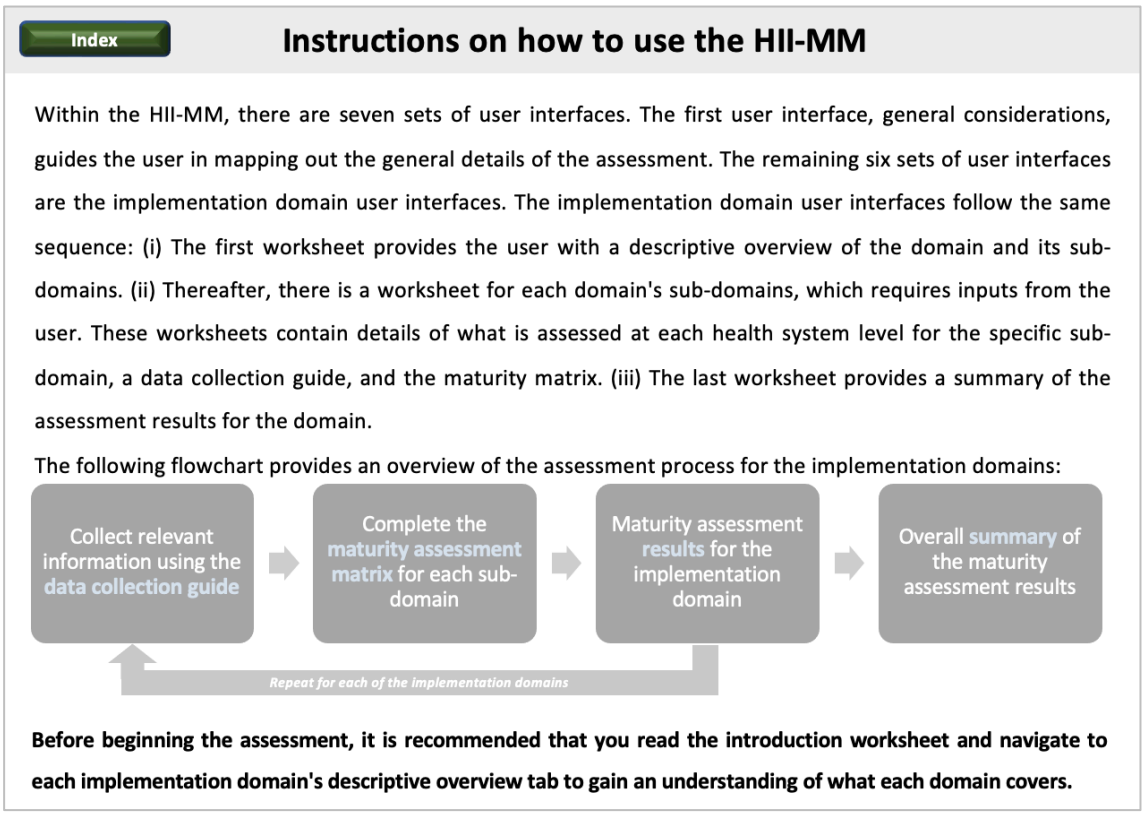


Figure 7.3: Section of the instructions page; refer to Section H.4 of Appendix H for complete instructions

Within the HII-MM, seven sets of user interfaces need to be completed. The first user interface, viz., the general considerations worksheet (see Section 7.3), guides the user in mapping out the general details of the assessment. The remaining six sets of user interfaces are the implementation domain user interfaces (see Section 7.4). As depicted in Figure 7.3, the sequence followed when completing a set of implementation domain user interfaces is to (i) collect relevant information using the data collection guides and (ii) complete the corresponding maturity assessment matrices using the information collected and insights gained. The HII-MM synthesises the information inserted into the domain's maturity assessment matrices and outputs results for that domain. Once all the user interfaces have been completed, an overall summary of the results is automatically generated (see Section 7.5).

7.3 HII-MM: GENERAL CONSIDERATIONS USER INTERFACE

As described in Section 7.2, the HII-MM's first user interface relates to general considerations. The objective of this interface is to guide the user in formulating the specific aspects necessary to complete the maturity assessment successfully. Three sets of general considerations are included in this interface: (i) the innovation being assessed, (ii) the health system levels, and (iii) the implementation process. First, the user is prompted to enter the assessment date; thereafter, information on the innovation and the challenge or gap it is addressing is requested. For the implementation process, the user is prompted to identify the stage of the process being assessed and map the stakeholders and processes present. Lastly, the user is requested to consider the health system setting and to define the specific health system levels that will be assessed. A section of the general considerations page is shown in Figure 7.4; the user is prompted to enter the relevant information into the red boxes. Refer to Section H.5 of Appendix H for the comprehensive general considerations page.

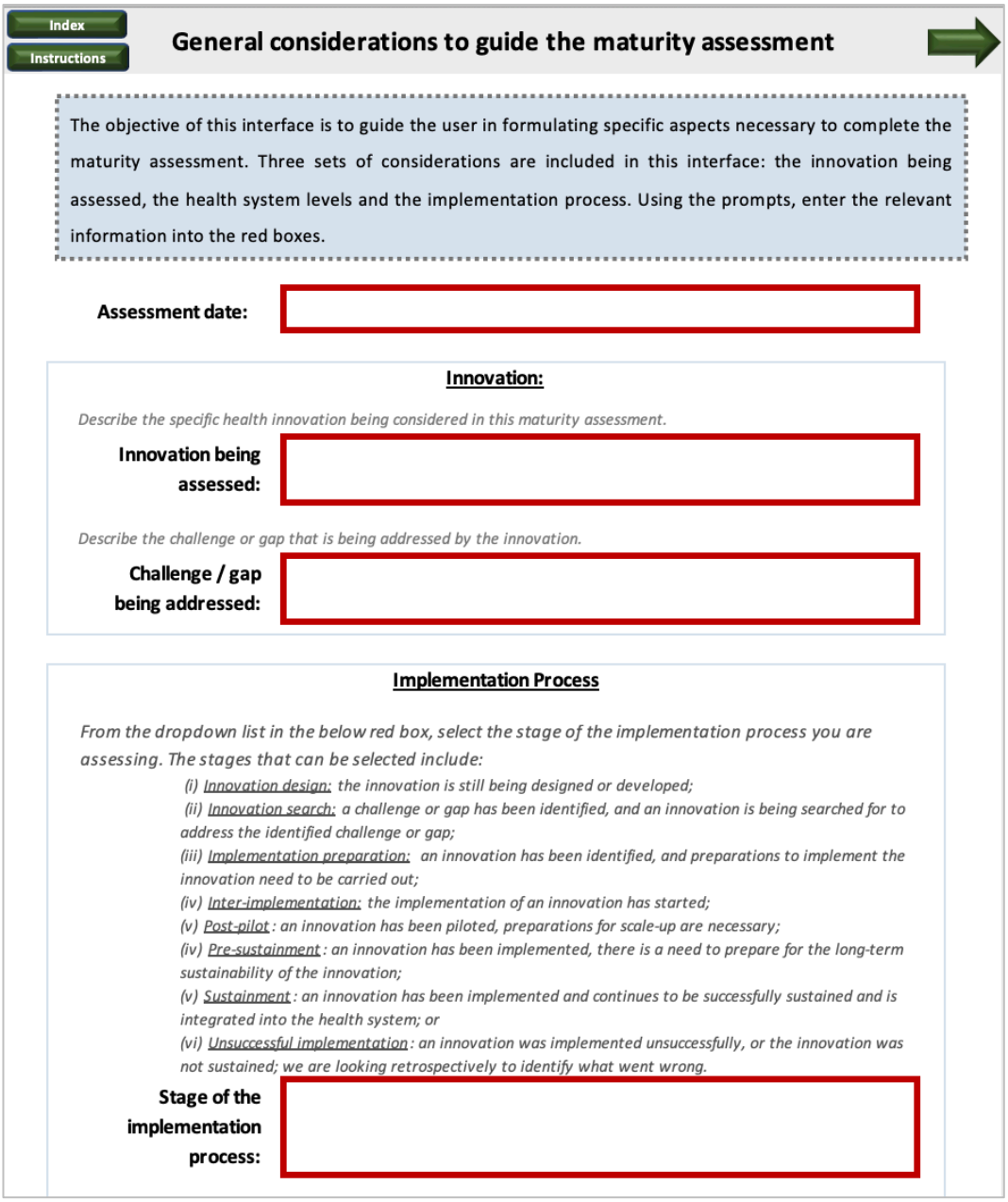


Figure 7.4: Section of the general considerations page; refer to Section H.5 of Appendix H

7.4 HII-MM: IMPLEMENTATION DOMAIN USER INTERFACES

As described in Section 7.2, there is a set of implementation domain user interfaces for each of the six domains. The implementation domain user interfaces consist of: (i) a domain overview page (see Figure 7.5 for an example), and (ii) three to four sub-domain maturity assessment pages (see Figure 7.6 for an example), and (iii) a domain results page (see Figure 7.7 for an example).

On the domain overview page, a domain description is provided, and an overview is given of the different sub-domains present within the domain; refer to the example in Figure 7.5. Additionally, a navigation diagram is presented on the domain overview page; the user can use the navigation diagram to move between domains and sub-domains, as there is no set order in which these have to be completed.

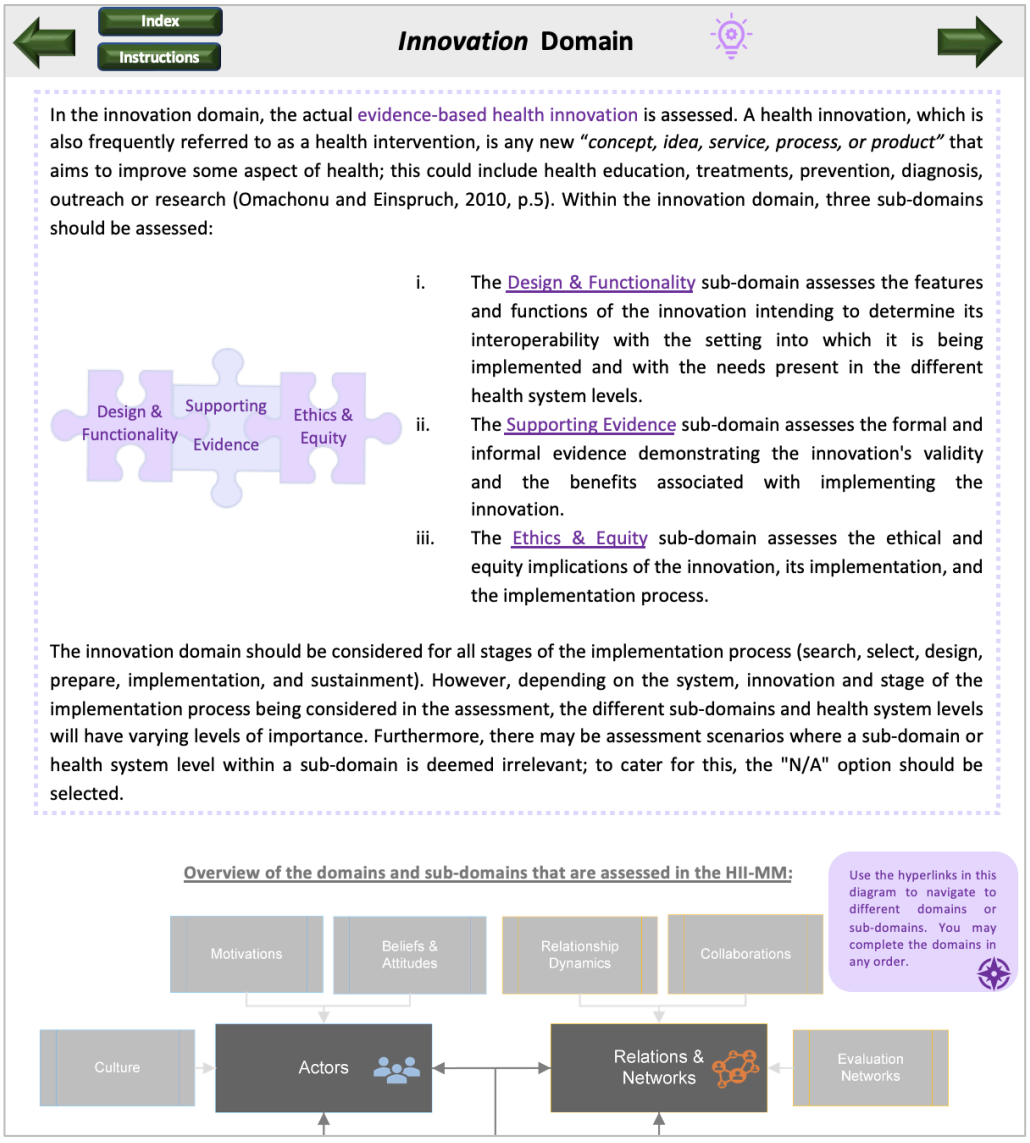


Figure 7.5: Example of a section of a domain overview page for the innovation domain

The maturity assessment page for a sub-domain begins with a discussion of what the sub-domain entails at each health system level. Then, a data collection guide is presented to guide the information collection process; data should be collected from various sources to reduce bias and increase accuracy. Figure 7.6 illustrates an example of the maturity assessment page.

The data collected should enable the user to complete the maturity assessment matrix. The matrix is presented just below the data collection guide. The health system levels are described on the vertical axis of the matrix and the health system statements are customised to each sub-domain. The maturity levels are described on the horizontal axis, and again, the maturity level statements are customised to each sub-domain. The matrix body comprises capability statements that describe the possible states at which a system, innovation or implementation process could be. The matrix works like a marking rubric in that the data collected for a sub-domain should be used to determine the capability statement most applicable to the assessed situation.

i) Maturity assessment for the *Innovation* sub-domain: DESIGN & FUNCTIONALITY

The innovation's design (features, characteristics) and functionality influence its interoperability with the different health system levels, its ability to function correctly in the health system, and whether it meets the needs present in the health system.

Skip to Matrix

What is assessed in this sub-domain?

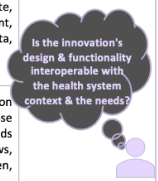
In this sub-domain, the innovation's design and functionality are assessed to determine whether it is interoperable with the needs present, the context in which it is being implemented and whether it functions correctly in the health system.

- At the **micro-community level**, the compatibility of the innovation with the socio-demographics and needs of the target community are assessed.
- At the **micro-provider level**, the compatibility of the innovation with the socio-demographics of the providers who are using the innovation, with the provider level processes, with the places in which the provider operates, and the needs of the providers are assessed.
- At the **meso and macro levels**, the interoperability of the innovation with the context and the needs, wants, or gaps present in the respective health system levels are assessed. The meso and macro levels assessment will depend on what the user specified in *General Considerations*.

Data collection guide:

Use the following points to guide your data collection process.

	Data Collection Guide	Possible Data Sources
1	**Describe the innovation under consideration**: - Consider the features/characteristics of the innovation. - Determine whether there are features of the innovation that are adaptable and ease of adaption. - What does the innovation do? - Does the innovation effectively perform its functions and consistently do what it's supposed to? - Determine whether it is possible to adjust the functions of the innovations. - If applicable, describe whether the innovation results are measurable or observable.	User manual, concept note, specification document, innovation company, pilot data, using the innovation
2	**Describe the attributes and needs of the community that will be the recipients of the innovation**: - Define the community's socio-demographics. - Consider the population's age, the language spoken, educational attainment, levels of literacy, and technological literacy. - Determine the wants and needs of the target community. - Identify potential gaps present within the target community. - Establish whether the target community was involved in the innovation's design.	Scoping interviews, population census, population disease burden, community needs assessment, scoping interviews, population disease burden, community gap analysis
3	**Describe the attributes and needs of the providers who will use/provide the service enabled by the innovation**: - Define the socio-demographics of the providers. - Consider the providers' age, the language spoken, educational attainment, levels of literacy, and technological literacy. - Determine the wants and needs of the providers. - Identify potential gaps within the providers or the organisation they function in. - Establish whether the providers were involved in the design of the innovation.	Scoping interviews, job deliverables/KPIs, population census, engagements with human resources, Needs assessment, scoping interviews, job deliverables/KPIs, provider gap analysis
4	**Describe the local environment in which the providers will use the innovation**: - Define the existing practices/processes that the providers operate in. - Consider existing information systems, metric systems, calendar systems, workflows, and requirements.	Organisational documents, time-motion studies, observation, scoping interviews
5	**Describe the features & needs present in the chosen meso-level**: - Define the meso-level context and any practices/processes present in the meso-level. Consider the environmental conditions, temperatures, dust, type of terrain, presence of natural disasters, information systems, practices, and procedures. - Determine the wants and needs present at the meso-level. - Identify potential gaps present at the meso-level. - Establish whether any stakeholders at the meso-level were involved in the innovation's design.	History of natural disasters, temperature records, natural terrain, plans, strategies, system information, Meso-level plans, strategies, aims or objectives; focus groups, meso-level gap analysis
6	**Describe the features & needs of the chosen macro-level**: - Define the macro-level context and any practices/processes present at the macro-level. Consider the health context, existing strategies, plans, and goals. - Determine the wants and needs present at the macro-level. - Identify potential gaps present at the macro-level. - Establish whether any stakeholders at the macro-level were involved in the innovation's design.	Plans, strategies, international organisation websites, Macro-level treaties, plans, strategies aims or objectives; focus groups, macro-level gap analysis
7	**Assess the innovation's functionality** - Determine whether the innovation is user-friendly for and understood by the community, providers, meso- and macro-level stakeholders. - Establish whether the innovation is functioning correctly.	Focus group, engagements with relevant stakeholders, pilot data, observational study



Maturity assessment matrix:

Using the data collection guide and the user interface (see the below table), identify the most appropriate maturity capability statement (see the statements for levels 0 to 5 in the table's body) for each health system level.

Selecting a maturity level		
	Select the maturity level for: **micro-community level**	N/A
	Select the maturity level for: **micro-provider level**	N/A
	Select the maturity level for: **meso health system level**	N/A
	Select the maturity level for: **macro health system level**	N/A

Design & Functionality user-interface:

Innovation sub-domain: **Design & Functionality**		Maturity Capability Levels					
		Level 0: No interoperability, does not function.	**Level 1:** Interoperability and functionality are inconsistent.	**Level 2:** Partially interoperable, adaptability is controlled.	**Level 3:** Interoperable with the system, interoperability and functionality is understood.	**Level 4:** Interoperability and functionality within the system are predictable and managed.	**Level 5:** Ability to continually adapt to ensure optimal functionality and continuous interoperability.
Health System Levels	**Micro: community** Socio-demography of the community. Community's needs / wants.	No socio-demographic interoperability. / Does not address community needs.	Inconsistent interoperability. / Interoperable with a minority of the community.	Partial interoperability with the community. Some adaptations are needed to improve interoperability.	Fully interoperable with the community. Interoperability understood.	Interoperability of the innovation with the community is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the community.
	Micro: provider Existing practices. Socio-demography of providers. Provider's needs / wants.	No socio-demographic interoperability. / Does not address provider needs. / Not interoperable with existing practices.	Inconsistent interoperability with providers. / Only interoperable with a few providers.	Partial interoperability with providers. Some adaptations are needed to improve interoperability.	Fully interoperable with providers. Interoperability understood.	Interoperability of the innovation with providers is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with providers.
	Meso Meso-level conditions, processes or practices. Meso-level needs / wants.	No interoperability with the meso-level. / Does not address meso-level needs.	Inconsistent or poor interoperability with the meso-level conditions, processes, practices or needs.	Partial interoperability with meso-level conditions, processes or practices. Some adaptations are needed to improve interoperability.	Fully interoperable with meso-level. Interoperability understood.	Interoperability of the innovation with the meso-level is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the changing meso-level.
	Macro Macro-level processes or practices. Macro-level needs / wants.	No interoperability with the macro-level. / Does not address macro needs.	Inconsistent or poor interoperability with macro-level processes, practices or needs.	Partial interoperability with macro-level. Some adaptations are needed to improve interoperability.	Fully interoperable with macro-level, interoperability understood.	Interoperability of the innovation with the macro-level is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the changing macro-level.

Innovation results | Index | Instructions

Figure 7.6: Example of a sub-domain maturity assessment page for the innovation sub-domain: design & functionality

Once the maturity assessments for a domain's sub-domains have been completed, the maturity assessment result for the implementation domain is presented. An example of a domain's results page is presented in Figure 7.7. The domain's average maturity scores are presented in the table on the left, and the sub-domains breakdown is presented in the table to the right. The radar charts graphically represent the health system and sub-domain maturity levels. Finally, the domain results page discusses how to interpret and improve the maturity levels.

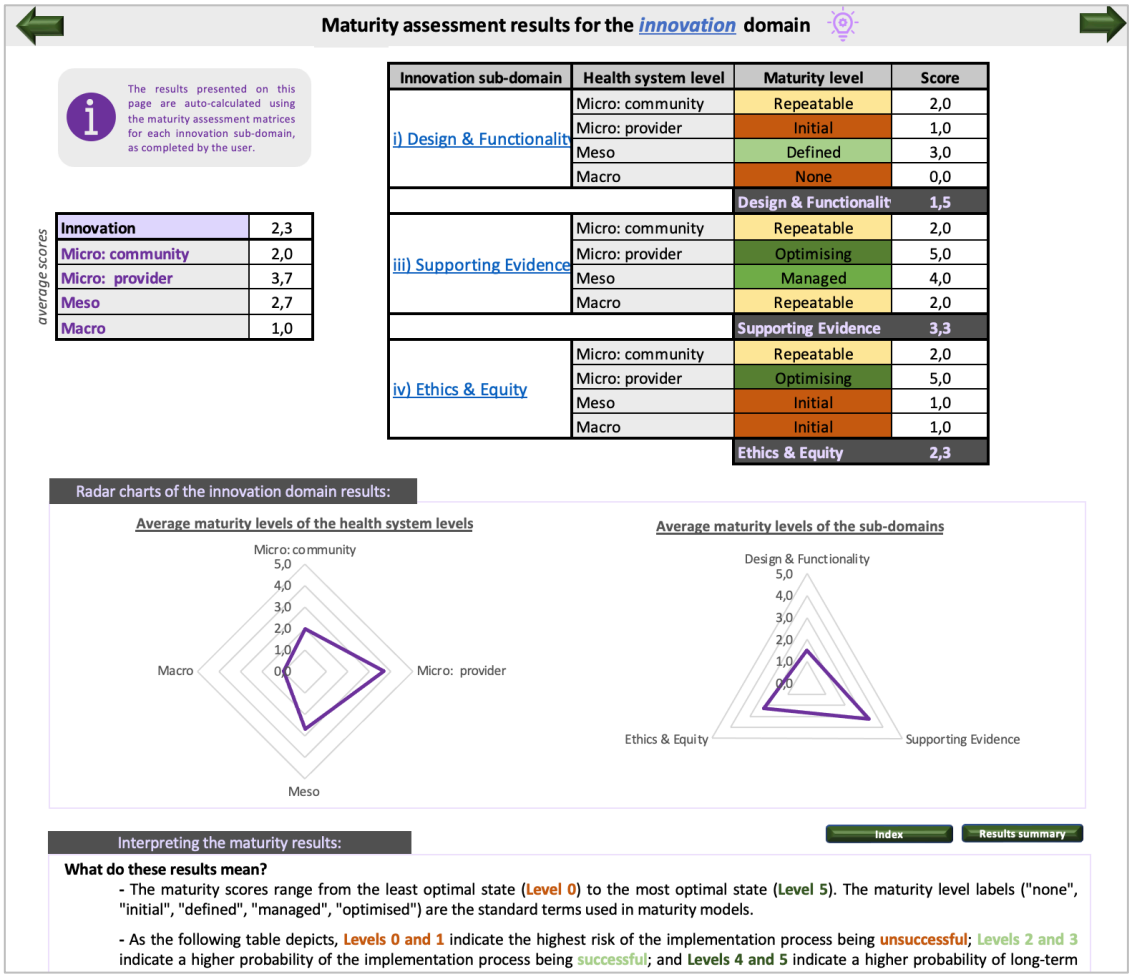


Figure 7.7: Example of a domain results page for the innovation domain (Note: the data shown in this example are for demonstrative purposes and do not reflect a real scenario)

As described in Sections 6.3.3 and 7.1, the maturity levels ("none", "initial", "defined", "managed", and "optimised") range from the least optimal, Level 0, to the most optimal, Level 5. In the context of the HII-MM, Levels 0 and 1 indicate the highest risk of the implementation process being unsuccessful; Levels 2 and 3 indicate a higher probability of the implementation process is successful, and Levels 4 and 5 indicate a higher probability of the long-term sustainability of the implemented innovation. It is not to say that achieving a low maturity score for one or multiple sub-domains, health system levels, or domains will result in the unsuccessful implementation of an innovation. Nor does achieving high maturity scores guarantee sustainability; this is because of (i) the complex nature of health and innovation systems, (ii) the intricate interactions between the different domains, sub-domains and health system levels, and (iii) the varying levels of impact that a sub-domain, domain or health system level will have on the implementation process – all of these will vary depending on the specific innovation and setting being assessed.

In order to improve maturity scores, the maturity levels should be used to identify areas where improvement initiatives should be focused. Low-scoring sub-domains and health system levels should be identified using radar charts or summary tables. The low-scoring areas represent gaps and are thus possible areas for improvement. When considering these, the user is advised to use their experience and insights to consider the effort spent and the benefits gained from carrying out an improvement initiative to address an identified gap. Existing implementation strategies that could be used as starting points to develop improvement strategies will be discussed in Section 7.5.

7.5 HII-MM: CONCLUDING SECTIONS

Once the maturity assessments of the six implementation domains have been completed, an overall summary is presented of the maturity assessment results. The assessment does not provide specific improvement processes; however, the results can be used to develop an improvement process because the maturity capability statements describe a pathway for improvement. An example of the summary results is depicted in Figure 7.8.

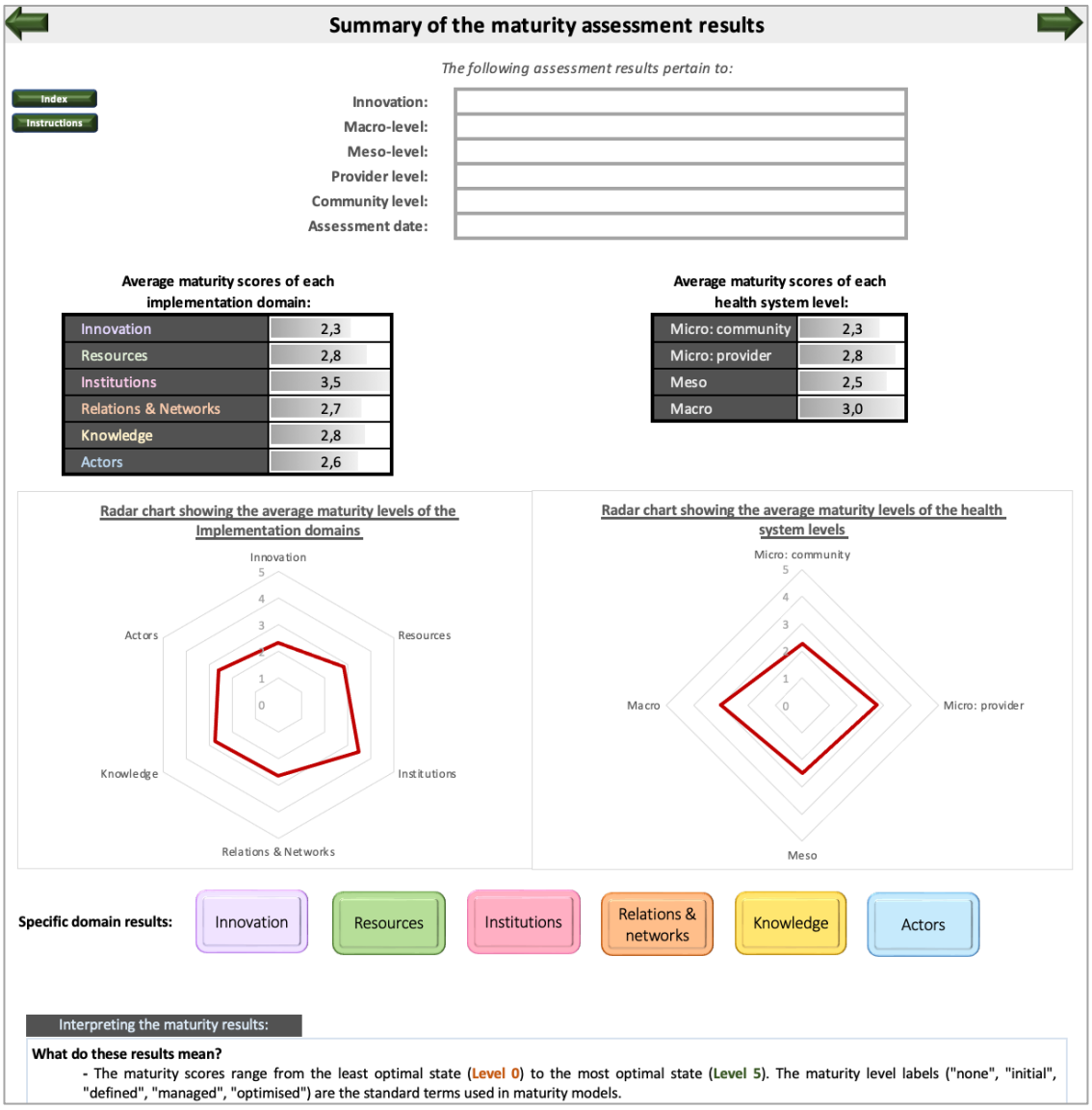


Figure 7.8: Example of the summary maturity assessment results (Note: the data shown in this example are for demonstrative purposes and do not reflect a real scenario)

The specific capabilities of the higher maturity levels should be considered, and strategies to achieve these capabilities should be developed to improve the maturity score of a sub-domain or health system level. Health system levels and domains do not all have to be at levels 3, 4 or 5 to ensure successful, sustainable innovation implementation. For example, it might create more value in terms of implementation success to increase the maturity of the design sub-domain to level 4 than increasing the maturity of the policies domain to level 4. When choosing an improvement initiative to address an identified gap, the impact and ease of different initiatives, given the available resources, should be evaluated to determine which initiative to prioritise (i.e., a cost-benefit analysis).

The summary results page is followed by the implementation strategies page, which lists potential strategies that could be leveraged to improve an implementation domain's score. Implementation strategies are the "*methods or techniques used to enhance the adoption, implementation, and sustainability*" of healthcare innovations (Powell *et al.*, 2015 p.2). A section of the implementation strategies page is depicted in Figure 7.9, and the complete page is presented in Section H.8, Appendix H. The implementation strategies listed on the page were extracted from the articles written by Powell *et al.* (2015) and Peters, Tran and Adam (2013). These articles were used to identify implementation strategies because they provide a succinct overview of potential implementation strategies, are published by respected platforms (Implementation Science Journal and the World Health Organization), and have been cited over 1000 and 500 times, respectively. This is by no means a complete list of implementation strategies; the objective of the list is to provide a starting point, prompting the user to design context-appropriate improvement initiatives.

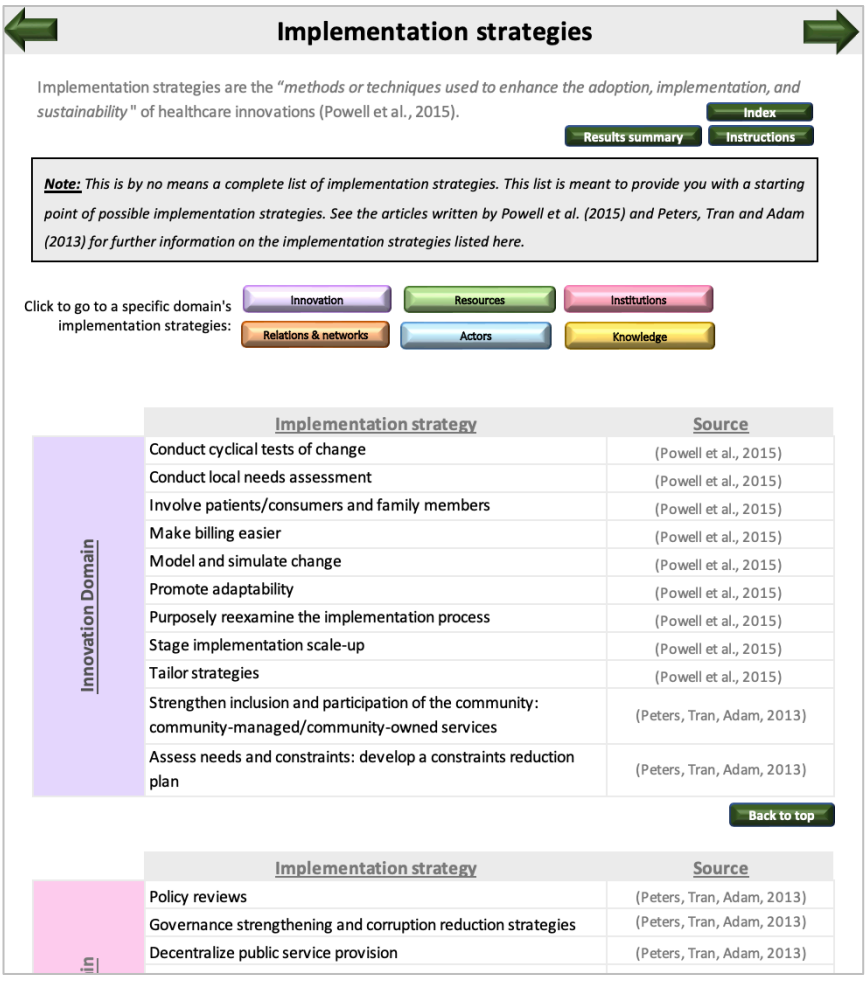


Figure 7.9: Section of the implementation strategies page

The last sheet of the HII-MM workbook is a list of references used in the workbook (refer to Section H.9, Appendix H).

7.6 OPERATIONAL IMPLICATIONS OF THE HII-MM

By performing the HII-MM assessment, the as-is state of the health innovation landscape is defined, facilitating an understanding of the system's current capability to implement a health innovation and the characteristics and properties that should be considered during an implementation process. Additionally, the HII-MM's maturity capability statements outline an improvement roadmap or maturation path, enabling improvement initiatives' development.

As described in Table 7.1, the HII-MM has numerous use scenarios, including the following; (i) designing an innovation, (ii) benchmarking to choose an innovation, (iii) searching for an appropriate innovation, (iv) preparing to implement an innovation, (v) informing change, (vi) guiding improvement initiatives, (vii) preparing for scale-up after a pilot, (vii) developing sustainability strategies, and (viii) understanding what went wrong in an unsuccessful implementation process. The HII-MM enables a systems analysis of a health innovation system; therefore, its results have implications for the wide range of stakeholders and levels of control in the micro-community, micro-provider, meso- and macro-health system levels. Thus, the operational implications of the HII-MM are its ability to promote and improve the successful and sustainable implementation of evidence-based health innovations into LMIC health systems.

7.7 CHAPTER 7: CONCLUSION

In this chapter, the HII-MM was operationalised using Microsoft Excel. The operationalised HII-MM consists of 40 spreadsheets, which comprise an introduction to the HII-MM, the recommended processes that should be followed when using the HII-MM, the general and implementation domain user interfaces, and concluding sections. The next chapter discusses the process followed to verify the HII-MM.

Chapter 8 HII-MM Verification and Refinement

This chapter describes the techniques used to verify and refine the preliminary maturity model. Verification relates to whether something is true or correct (Cambridge English Dictionary, 2019b); in the context of this study, verification is done to ensure that the structure and content of the maturity model have theoretical integrity and meet the requirement specifications. The verification process consists of two sets of verification interviews and a verification case study. After each stage of the verification process, the maturity model was iteratively refined to form the final HII-MM. One publication emulates Section 8.3 of this chapter, titled: *Investigating the barriers and facilitators to implementing an eHealth innovation in a resource-constrained setting: A South African case study* (Leonard, De Kock and Bam, 2020b). It was presented and published in the 2020 IEEE International Conference on Engineering, Technology and Innovation proceedings.

Chapter 8 Outline:

8.1 VERIFICATION METHODOLOGY

Figure 8.1 shows the process followed to evaluate the maturity model. As depicted in Figure 8.1, the preliminary HII-MM, presented in Appendix F (App. F) undergoes three verification phases; after each verification phase, the identified refinements are incorporated into the maturity model. This iterative refinement results in the final maturity model – the HII-MM, presented in Chapter 6 (Chp.6) and operationalised in Chapter 7. Details of the verification methodology are described in Chapter 2, Section 2.3.3.

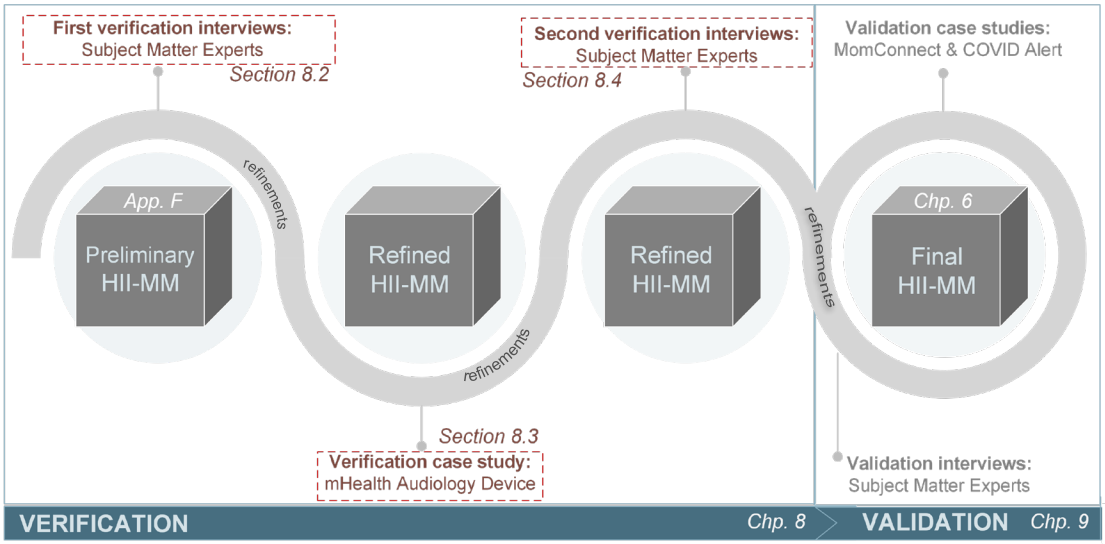


Figure 8.1: Maturity model evaluative process – verification phase

The two sets of verification interviews were undertaken to meet RO 3, defined in Chapter 1, Section 1.4 (i.e., to validate and verify the ability of the maturity model to practically and holistically assess the facilitators and barriers to implementation present in an LMIC health innovation system). More specifically, to address sub-objective RO.3.1, which relates to the need *to receive inputs from subject matter experts to verify the content and structure of the approach*. The verification interviews were leveraged to identify specific areas for refinement to ensure that the maturity model can indeed be used to meet the aim of the study.

The purpose of the verification case study was to verify the structure and practicality of the maturity model. The insights gained while performing the verification case study are used to identify specific areas for refining the maturity model to improve its usability.

8.2 FIRST VERIFICATION INTERVIEWS

SME1 to SME6 participated in the first verification interviews (see Appendix I, Section I.5 for the list of SMEs and their area and regions of expertise). The basic interview methodology followed throughout this study is detailed in Chapter 2, Section 2.3.3.1. The questions asked during the first verification interviews were developed using the pre-defined design restrictions (described in Section 5.1.3) and the aim of the study (described in Section 1.3). Interviewees were requested to reflect on and verify the maturity model's structure and content. The questions covered during the first verification interviews are presented in Section I.1 of Appendix I.

8.2.1 First Verification Interviews Outcomes

The outcomes from the first set of verification interviews are presented in Sections 8.2.1.1 to 8.2.1.4 below. The outcomes are structured according to the three dimensions of the maturity model (i) implementation domains, Section 8.2.1.1, (ii) health system levels, Section 8.2.1.2, and (iii) maturity levels, Section 8.2.1.3. Results from the general discussions, in addition to these three dimensions, are described in Section 8.2.1.4. The specific refinements made to the maturity model after the first verification interviews are described in Section 8.2.2.

8.2.1.1 First Verification Interviews: Implementation Domains

As described in Appendix F, the preliminary maturity model comprised seven implementation domains, namely: (i) innovation, (ii) resources, (iii) institutions, (iv) relations & networks, (v) actors, (vi) knowledge, and (vii) context. The implementation domains describe the concepts within a health innovation system that influence the implementation process. The feedback given by the SMEs, where specific refinements to the respective implementation domains were suggested, is discussed in Table 8.1. For each concern raised or refinement suggested, the methods of incorporating the feedback into the maturity model are discussed. A detailed discussion of the implementation domains verification results is presented in Appendix I, Section I.6 a) to f).

Table 8.1: First verification interview – SME feedback on the implementation domains

Domain	Aspect	SME feedback	Discussion
Innovation	Perception sub-domain	SME1 was uncertain about having perception as part of the innovation domain.	Perception is included in the innovation domain because the perceived threats and benefits are specific to the innovation being implemented. However, the researcher acknowledges that the term 'perception' may also be linked to the 'actors' domain. Therefore, the term perception will be changed to 'threats & benefits' to reduce ambiguity.
Innovation	Degree of novelty sub-domain	Both SME1 and SME2 stated that an innovation is not only classified using the degree of novelty but there are also two dimensions that should be used when classifying an innovation: novelty and impact.	The degree of novelty sub-domain was changed to 'type' to ensure that the subdomain is inclusive of both methods of classifying an innovation. The 'type' sub-domain includes both the degree of novelty and the level of impact.
Innovation	Design sub-domain	SME3 stated that 'durability and longevity', which were part of the description of the design sub-domain, are more suited to the resources domain, as they relate to the availability of maintenance and finances.	The researcher agreed with the SME. Durability and longevity will thus be removed from the design sub-domain and incorporated into the description of the resource domain.
Innovation	Evidence strength sub-domain	SME3 questioned whether the quality of information was covered in the maturity model.	Information quality is covered in various domains in the maturity model, including the evidence strength sub-domain, the dissemination sub-domain and the evaluation, feedback & communication sub-domain.
Resources	Time sub-domain	SME3 and SME5 suggested combining the time sub-domain with the human sub-domain, arguing that time relies on the human resources in the system.	The researcher agreed with the SMEs, and thus the time sub-domain will be integrated with the human sub-domain to simplify the resources domain.
Institutions	Institutions domain	SME1 recommended defining 'institutions' in the maturity model so that people know what it includes.	Definitions will be provided for the implementation domains and sub-domains to ensure that the assessor understands the maturity model constructs.
Institutions	Political priorities sub-domain	SME3 stated that the leadership direction in a country, which will change as new leaders come into power, should be considered under political priorities.	The changing political priorities associated with changing leadership will thus be considered in the political priorities' description.
Institutions	Standards & guidelines sub-domain	SME5 questioned whether the presence of an implementation partner is considered in the maturity model.	The presence of an implementation partner is considered in the relations & networks sub-domain: collaboration.
Relations & networks	Collaboration sub-domain	SME3 stated that, when assessing collaborations, intra-professional collaborations should be assessed alongside inter-professional collaborations (giving an example of collaborations needed between health professionals within a facility).	Intra-professional collaborations will be added to the explanation of the collaboration to address this.

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Domain	Aspect	SME feedback	Discussion
Relations & networks	Relationships & leadership sub-domain	Considering the description of the relationships & leadership sub-domain, SME6 suggested linking the roles and responsibilities to specific processes or activities.	The common roles and responsibilities found during the implementation process will be specified to address this.
Actors	Culture sub-domain	SME3 suggested including change resistance, which is part of the culture sub-domain, as a separate sub-domain of the actors domain.	Change resistance is an important component; however, resistance to change tends to result from other aspects in the culture sub-domain. Seeing that change resistance integrates with the other aspects in the culture sub-domain, separating it has not been deemed necessary.
Actors	Motivations & incentives sub-domain	SME6 suggested including the negative incentives or impacts (disincentives) as part of this sub-domain. An example of a disincentive would be requiring health professionals to use their mobile phones and cellular data to capture information.	It is important that the motivations & incentives sub-domain covers the potential negative incentives. Therefore, the subdomain will be renamed “motivations, incentives & disincentives”.
Context	Socio-cultural sub-domain	SME1 suggested integrating the socio-cultural sub-domain with the culture sub-domain in the actors domain.	The researcher agreed with the SME that the socio-cultural sub-domain is closely linked to and overlaps with the macro-level culture sub-domain in the actors domain. The socio-cultural sub-domain will thus be merged with the culture sub-domain.
Context	Environmental sub-domain	SME1 and SME2 suggested integrating the environmental sub-domain with the physical sub-domain in the resources domain.	The researcher agreed with the SMEs that the environmental sub-domain is closely linked to and overlaps with the macro-level of the physical sub-domain in the resources domain. The environmental sub-domain will be merged with the physical sub-domain.
Context	Political sub-domain	SME3 suggested integrating the political sub-domain with the political priorities sub-domain in the institutions domain.	The researcher agreed with the SME that the political sub-domain is closely linked to and overlaps with the macro-level of the political priorities sub-domain in the institutions domain. The political sub-domain will thus be merged with the political priorities sub-domain.

While the SMEs who participated in the first verification interviews agreed that context is an important implementation domain, some concerns were raised about the context sub-domains overlapping extensively with the other implementation domains. The context domain was thus removed after the first verification interviews, and its sub-domains were all integrated into other domains, as described in Table 8.1.

8.2.1.2 First Verification Interviews: Health System Levels

The feedback given by the SMEs, where specific refinements were suggested to the health system levels, is discussed in Table 8.2. A detailed discussion of the verification results for the health system levels is presented in Appendix I, Section I.6 g).

Table 8.2: First verification interview – SME feedback on the health system levels dimension

Level	SME feedback	Discussion
Meso-level	SME6 recommended giving the user of the maturity model clear guidance on determining what the sub-national health level should include. This would be necessary for a country like South Africa, whose health system is three-tiered (national, provincial, and district).	The recommendation provided by the SME will be incorporated into the instructions on how to use the maturity model.

8.2.1.3 First Verification Interviews: Maturity Levels

All SMEs agreed that maturity levels are an appropriate method of assessing implementation, with SME6 stating that "*the use of maturity models is now fairly well established*." SME2 contemplated the value of maturity models, stating: "*The value of maturity models is there. For maturity levels, we don't always need to be at a 4 or 5; in some instances, we do not need to be mature – it's strategic*." The SMEs suggested no specific refinements concerning the maturity levels.

8.2.1.4 First Verification Interviews: General Discussions and Suggestions

The feedback given by the SMEs, where general refinements were suggested to the maturity model, is discussed in Table 8.3.

Table 8.3: First verification interview – SME feedback on the usability and usefulness of the maturity model

Aspect	SME feedback	Discussion
Users	SME1 and SME2 stated that the maturity model's users need to be defined.	The maturity model's users are described in Section 6.2.3. The maturity model's users will be defined in the introductory section of the maturity model.
Implementation domains	SME1 and SME3 enquired about the place that processes (implementation processes or project management processes) have in the maturity model.	While the maturity model does not have a specific domain for processes, there are process components throughout each implementation domain. Furthermore, the different health system levels are fundamentally made up of processes. It was not deemed necessary to have a separate process domain.
Conducting the assessment	SME6 and SME2 made suggestions for conducting the maturity assessment. SME2 emphasised the need for definitions, and SME6 suggested interpreting the maturity model into questions to get an accurate picture of the maturity levels.	The researcher agreed with the SMEs; definitions will be incorporated into the maturity model, and the maturity model will include data collection guides to help guide the assessment.
Results interpretation	SME1, SME2, SME5, and SME6 enquired about interpreting the results of applying the maturity model.	How the results are interpreted and used will vary between case studies. However, it is deemed necessary to provide the maturity model's users with guidance on interpreting the results.

8.2.2 Refinements Based on the First Verification Interviews

The feedback given by the SMEs during the first verification interviews was used to refine the preliminary maturity model. Table 8.4 summarises the refinements made to the first maturity model. The modifications made are linked to the interview results described in Section 8.2.1.

Table 8.4: Summary of the refinements made to the maturity model after the first verification interviews

No.	Component(s)	Refinement	Refer to
1	Innovation sub-domain: Perception	Changed to “Threats & benefits”	Table 8.1
2	Innovation sub-domain: Degree of novelty	Changed to “Type”	Table 8.1
3	Actors sub-domain: Motivations & incentives	Changed to “Motivations, incentives & disincentives”	Table 8.1
4	Resources sub-domain: Time	Merged with the resources sub-domain: Human	Table 8.1
5	Context sub-domain: Socio-cultural	Merged with the actors sub-domain: Culture	Table 8.1
6	Context sub-domain: Environmental	Merged with the resources sub-domain: Physical	Table 8.1
7	Context sub-domain: Political	Merged with the institutions sub-domain: Political priorities	Table 8.1
8	Innovation sub-domain: Design Institutions domain Institutions sub-domain: Political priorities Relations & networks sub-domain: Collaboration Relations & networks sub-domain: Relationships & leadership	Adjusting definitions/descriptions	Table 8.1
9	Overall maturity model	Develop instructions on how to use the maturity model	Table 8.2 Table 8.3

In addition to the refinements made according to the SME interviews, the researcher used the insights gained from the interviews to make three additional refinements to the maturity model. The first two refinements were to merge the overlapping innovation sub-domains. The innovation domain was identified as a domain that required simplification because some of the innovation sub-domains were overlapping resulting in certain aspects being assessed twice. Furthermore, the innovation domain had seven sub-domains, whereas the rest of the implementation domains had a maximum of four sub-domains. The innovation sub-domains “Type” and “Threats & benefits” thus merged; this was done because the degree of novelty of and the impact of the innovation are directly related to the perceived threats and benefits surrounding the innovation. The second additional refinement was to merge the innovation subdomains “Design” and “Interoperability & adaptability”. These innovation sub-domains were merged because the design of the innovation (including the language used, the features present etc.) directly affects the innovation’s interoperability with its context, and the innovation’s design also influences whether the innovation can be or needs to be adapted.

The third additional refinement made was merging the knowledge sub-domains: capacity and knowledge base. These were merged because it became difficult to separate the knowledge quality (knowledge base) from the knowledge quantity (capacity) when describing the sub-domains for each maturity level. The progression of the combined knowledge base & capacity domain through the maturity levels would begin with the knowledge present in the system being insufficient and of

insufficient quality at level 0, and as the maturity levels increase, the amount of quality knowledge present in the system would increase too.

The structural refinements completed after the first SME verification interviews focused on the implementation domains and subdomains. There were no refinements made to the maturity levels or health system levels. The refined implementation domains and corresponding subdomains are displayed in Figure 8.2.

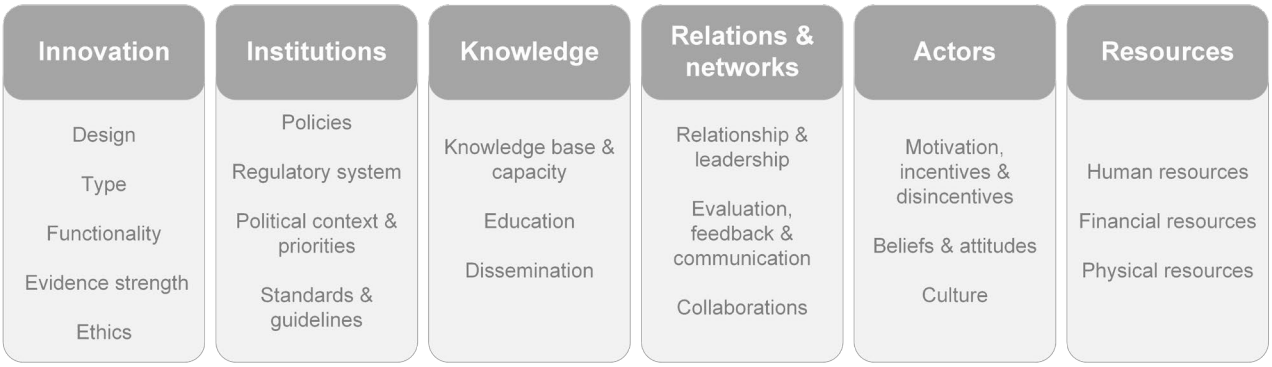

Figure 8.2: Refined implementation domains and sub-domains after first verification interviews

8.3 VERIFICATION CASE STUDY: MHEALTH AUDIOLOGY DEVICE

After the first verification interviews, a verification case study was carried out. It was performed using the refined maturity model, highlighted in red in Figure 8.3. The basic case study protocol followed throughout this study is detailed in Chapter 2, Section 2.3.3.2.

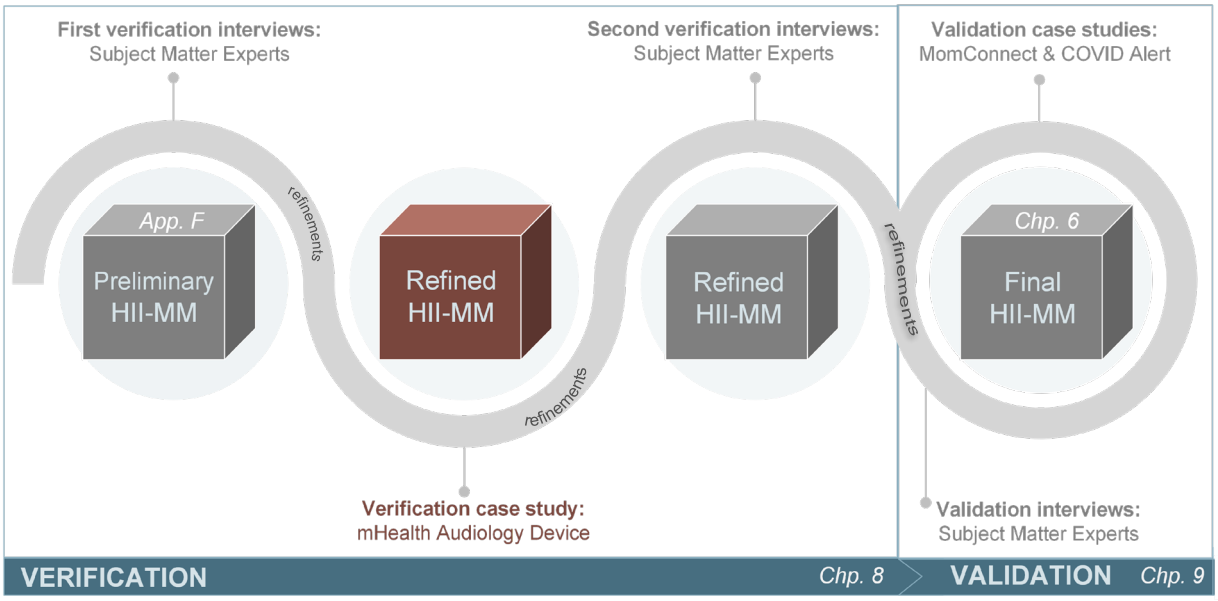

Figure 8.3: Refined maturity model used for the verification case study

8.3.1 Performing the Verification Case Study

The verification case study was performed on a decentralised hearing and vision screening device implemented by CHWs over two years in early childhood development centres and schools in

Tembisa, South Africa. The screening device comprises calibrated headphones and an evidence-based mobile application loaded onto a smartphone; it is an affordable and mobile alternative to traditional audiology devices.

Data were collected from a wide range of sources, including, but not limited to, (i) the health innovation company's website, (ii) academic articles, (iii) online news articles about the health innovation, (iv) other online sources, including the WHO website, (v) an interview with the health innovation company's project manager, and (vi) the project report, which was supplied to the researcher by the health innovation company. The guiding questions used to gather information from the interviewee for the verification interview are presented in Section J.1 of Appendix J.

During the analysis and summary phase of the verification case study, the data collected were categorised into the refined implementation sub-domains (refer to Figure 8.2) and then analysed to determine the maturity of each implementation sub-domains at each health system level. The maturity levels were examined to produce conclusions and recommendations for the case study. As the verification case study was used to refine the maturity model further, its results are not presented in the main text; the maturity assessment results, ensuing from performing the verification case study, are presented in Section J.1 of Appendix J.

8.3.2 Verification Case Study Outcomes

The insights gained while performing the verification case study were used to identify specific areas of refinement. The practical insights gained are discussed in Table 8.5.

Table 8.5: Practical insights into the maturity model

Aspect	Practical Insight
Innovation & health system levels	Before beginning the maturity assessment, the assessor must understand and explicitly describe the innovation and health system levels.
User Interfaces	The usability of the user interfaces was identified as an area needing improvement. The user interfaces need to be more self-explanatory for users unfamiliar with maturity models.
General	The verification case study highlighted the subjective nature of a maturity assessment, which could lead to social desirability bias by assessors or interviewees. There is thus a need to emphasise that the assessment is meant to determine gaps in the health implementation landscape, not to judge performance.

8.3.3 Refinements Based on the Verification Case Study

The practical insights gained while performing the verification case study were used to refine the maturity model further, and the refinements made are described in Table 8.6. No structural refinements were made to the maturity model; the refinements resulting from the verification case study were focused on improving the maturity model's usability.

Table 8.6: Summary of the modifications made to the maturity model after the verification case study

No.	Aspect	Refinements	Refer to
1	Innovation & health system levels	An additional section – the so-called general considerations section – was added to the maturity model that the user would be required to complete before starting the assessment. This section requires the user to describe the health system, innovation(s), and implementation process under consideration.	Table 8.5
2	Implementation sub-domain user interfaces	A *data collection guide* was developed for each user interface to improve the maturity model's usability. The data collection guides ensure a more structured technique for obtaining the necessary information to complete the maturity model assessment.	Table 8.5
3	General	A section consisting of FAQs was added to the maturity model. The FAQs within the UNICEF (2014) Supply Chain Maturity Scorecard were used to develop the FAQs. In addition to the FAQs, an introductory section, an overview section and an instructional section were added to operationalise the maturity model further.	Table 8.5

8.4 SECOND VERIFICATION INTERVIEWS

After the verification case study, the second set of verification interviews was carried out. These were performed using the refined maturity model, highlighted in red in Figure 8.4. SME7 to SME33 participated in the second verification interviews (see Appendix I, Section I.5 for the list of SMEs and their area and regions of expertise). The basic interview methodology followed throughout this study is detailed in Chapter 2, Section 2.3.3.1. The specific questions covered during the second set of verification interviews are presented in Section I.2 of Appendix I.

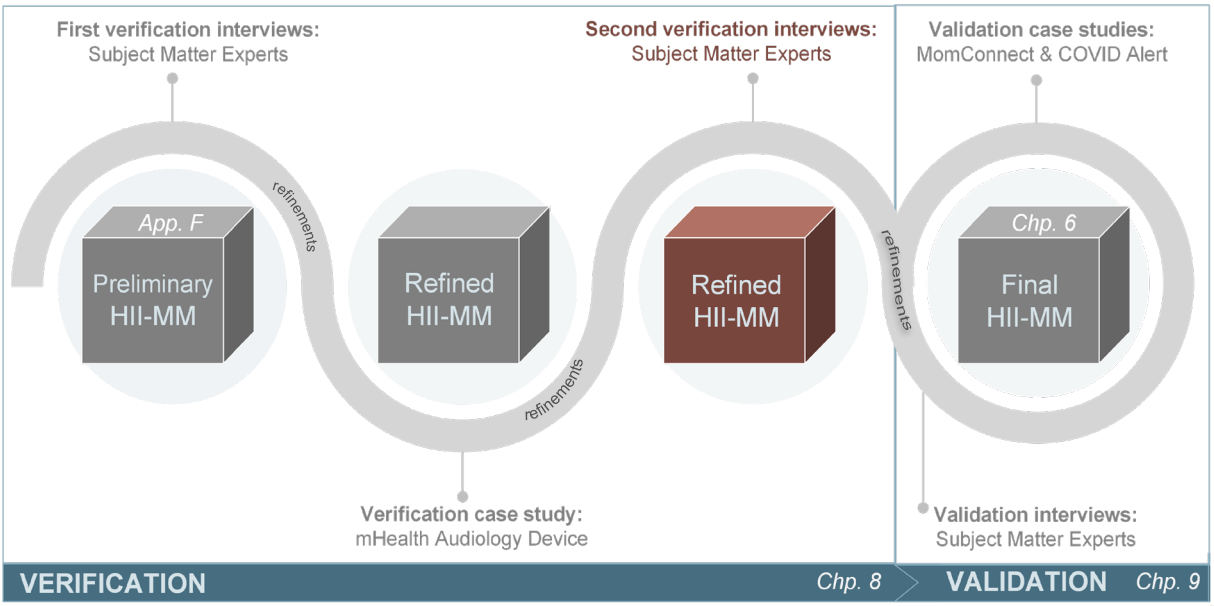

Figure 8.4: Refined maturity model used for the second verification interviews

8.4.1 Second Verification Interviews Outcomes

The outcomes from the second verification interviews are presented in Sections 8.4.1.1 to 8.4.1.4. The outcomes are structured according to the three dimensions of the preliminary maturity model, namely: (i) implementation domains, Section 8.4.1.1, (ii) health system levels, Section 8.4.1.2 and (iii) maturity levels, Section 8.4.1.3. In addition to these three dimensions, results from the general discussions are described in Section 8.4.1.4. The specific refinements made to the maturity model after the second verification interviews are described in Section 8.4.2.

8.4.1.1 Second Verification Interviews: Implementation Domains

The refined maturity model used in the second verification interviews comprised six implementation domains, i.e., (i) innovation, (ii) resources, (iii) institutions, (iv) relations & networks, (v) actors, and (vi) knowledge. A detailed discussion of the implementation domain verification results is presented in Appendix I, Section I.6. The feedback given by the SMEs where specific refinements were suggested to the respective implementation domains is discussed in Table 8.7. For each concern raised or refinement suggested, the methods of incorporating the feedback into the maturity model are discussed.

Table 8.7: Second verification interviews – SME feedback on the implementation domains

Domain	Aspect	SME feedback	Discussion
Innovation	Type sub-domain	During the second verification interviews, it was noted that the type sub-domain is very similar to the beliefs & attitudes sub-domain within the actors domain.	The type sub-domain was merged with the beliefs & attitudes sub-domain. The type of innovation is said to influence the negative and positive perceptions around the innovation, which is directly linked to a person's beliefs about the innovation.
Innovation	Design sub-domain	SME26 recommended adding technological literacy to the design sub-domain.	Technological literacy was added to the design sub-domain's data collection guide.
Innovation	Evidence strength sub-domain	Both SME24 and SME16 discussed the need to consider less formal evidence, particularly for innovations developed in LMICs, that might not have resources to develop a strong evidence base, i.e., reverse innovation or frugal innovation. SME17 discussed the need to consider the differing levels of evidence strength associated with the different stages of an innovation's evolution.	To ensure that the less formal methods of evidence are covered in the sub-domain, the sub-domain's name was changed to 'supporting evidence', and the maturity capability statements were adjusted to represent both formal and informal evidence.
Innovation	Ethics sub-domain	SME8 and SME28 suggested that equity be explicitly covered in the ethics sub-domain.	The researcher agreed with this suggestion and incorporated equity into the ethics sub-domain. The ethics sub-domain was renamed 'ethics & equity', and the maturity capability statements were adjusted to include equity considerations.
Innovation	Ethics sub-domain	SME24 and SME30 suggested additional considerations for the ethics sub-domain, namely, the social and cultural security of the community and any unintended consequences of the innovation.	The *ethics & equity* sub-domain data collection guide incorporated social and cultural security and unintended consequences.
Innovation	General considerations	SME17 highlighted that the gap the innovation is addressing should be stated upfront.	A prompt to enter the gap or challenge motivating the innovation's implementation and/or design was added to the *general considerations* user interface.
Resources	Physical resources sub-domain	SME7 stated that the 'physical resources' name is not intuitive.	The name was adjusted to 'infrastructure, services & physical resources' to better encompass the aspects of the sub-domain.
Resources	Physical resources sub-domain	SME27 discussed the scenarios in which physical resources were reflected as being present in the system but not necessarily available where or when needed.	The maturity capability statements for the *infrastructure, services & physical resources* sub-domain were expanded to consider both the availability and the presence of the infrastructure, services and physical resources.
Resources	Physical resources sub-domain	SME7 felt that the physical resources sub-domain should explicitly mention information systems. In addition, SME29 stated that the technological infrastructure should be	Technological infrastructure and information systems were added to the data collection guide of the *infrastructure, services & physical resources* sub-domain. Technical support resources were

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Domain	Aspect	SME feedback	Discussion
		explicitly mentioned, and SME21 discussed the explicit inclusion of technical support resources.	not included in the sub-domain as this aspect is already sufficiently covered by the sub-domain's maintenance considerations.
Resources	Financial resources sub-domain	SME23 and SME24 recommended including the general financial system under the financial resources sub-domain.	The researcher agreed that it is important to consider the general financing of the health system in addition to the specific health innovation financing. The general financial system would consider the presence of health insurance systems and finances available to maintain health workers, facilities and equipment. This was incorporated into the financial resources data collection guide.
Resources	Resources domain	SME16 recommended greater flexibility within the resources domain, pointing out that the financial sub-domain places a greater emphasis on financing for tangible innovations, and financing might be a smaller consideration for intangible innovations (e.g., new procedures).	The requirement to complete all the sub-domain fields was adjusted to cater for different innovations, enabling the user to choose the relevant sub-domains or health levels and omit the irrelevant sub-domains. In addition, statements discussing the weightings of different domains were included in the maturity model, emphasising that not all domains and sub-domains will carry equal weight; weightings will differ depending on the innovation under consideration and the health system, generally.
Institutions	Institutions domain	SME28 recommended defining the differences between policies and regulatory systems.	While a definition page had been provided to the SMEs, there was still a discussion around the difference between the *policies* and *regulatory system* sub-domains. While these two sub-domains are interrelated, they are still fundamentally different and, thus, should not be combined. To further differentiate the two sub-domains, their definitions were expanded, and the regulatory system sub-domain was renamed 'laws & regulations'.
Institutions	Institutions domain	SME30 emphasised that the interrelationships of the different sub-domains within institutions should be included throughout the institutions domain.	Within the institutions sub-domain, the capability statements for levels 4 and 5 were adjusted to include the collaboration between policies, regulations, standards & guidelines and institutional priorities.
Institutions	Political context & priorities sub-domain	SME9 suggested that the international community be emphasised within the political context & priorities sub-domain.	The political context & priorities sub-domain was renamed 'institutions & priorities' to better accommodate the international community in the institutions domain.
Institutions	Health system levels in the: Policies, Regulations, and Standards & guidelines sub-domains	SME26, SME22, SME17 and SME27 recommended allowing for the assessment of community-level legislatures, meso-level legislatures, community policies and community standards & guidelines. The first paragraph following this	To create more flexibility within the institutions sub-domains, the assessment of the relevant micro-community, micro-provider and meso-levels was enabled.

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Domain	Aspect	SME feedback	Discussion
		table presents a supporting discussion on the institutions domain.	
Relations & networks	Collaborations sub-domain	SME20 recommended explicitly including the private-public sector collaborations.	The public-private perspective was incorporated into the collaborations sub-domain's data collection guide.
Relations & networks	Relationships & leadership sub-domain	SME7 recommended including the perspective of community members who hold healthcare workers accountable.	The perspective of the community holding providers accountable was incorporated into the relationships & leadership sub-domain's data collection guide.
Relations & networks	Evaluation, feedback & communication sub-domain	SME9 suggested that the evaluation, feedback & communication sub-domain should evaluate how the community feels about the innovation.	The perspective of the community or providers evaluating the innovation and providing feedback to improve the implementation process was incorporated into the maturity capability statements in the evaluation, feedback & communication sub-domain.
Actors	Culture sub-domain	When discussing the culture sub-domain, SME17 recommended including proxy indicators. For example, when deciding if an organisation is susceptible to change, one should investigate how many innovations an organisation implemented in the past ten years.	The maturity model is intended to be usable in an extensive range of LMICs, and for a variety of innovations, proxy indicators could limit the applicability of the maturity model. Thus, proxy indicators were not included in the maturity model.
Actors	Beliefs & attitudes sub-domain	When discussing the beliefs & attitudes sub-domain, SME10 emphasised the importance of including change management.	Change management was explicitly included in the beliefs & attitudes sub-domain capability statements.
Actors	Actors sub-domains	There were recommendations to better differentiate between the motivations, incentives & disincentives sub-domain and the beliefs & attitudes sub-domain.	To better differentiate between the two sub-domains, the name of the *motivations, incentives & disincentives* sub-domain was simplified to 'motivations'. Additionally, the definitions of both sub-domains were expanded to enable a better understanding of and differentiation between them.
Actors	Actors sub-domains	SME16 stated that from their experience in implementing procedural innovations, the sub-domains within the actors domain would not be relevant at the community level.	Many SMEs have emphasised the importance of the actors domain at all health system levels. Thus, the community level in the actors domain was not removed. However, the inclusion of N/A as an option across the maturity assessment user interfaces enables users to exclude sub-domains or health system levels that might not be relevant to the specific scenario being considered.
Knowledge	Education sub-domain	SME16 specified that there is a need to consider education and training around the innovation and the problem or challenge it is being used to address.	The knowledge of and education around the problem were included in the data collection guide, and the sub-domain was renamed 'education & training' to highlight the importance of training.

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Domain	Aspect	SME feedback	Discussion
Knowledge	Education sub-domain	SME20 suggested that supportive supervision be included in the education sub-domain to ensure that passive forms of education (i.e., supportive supervision) are also covered.	To ensure the education sub-domain is more comprehensive, supportive supervision was incorporated into the sub-domain.
Knowledge	Dissemination sub-domain	SME22 discussed their interpretation of dissemination as a "*top-down kind of process",* which is not always the case.	The maturity model's definition of dissemination is the action of spreading something, including top-down and bottom-up spread. However, the discussion around dissemination led the researcher to consider the active nature of dissemination. To ensure that passive spread is also considered, diffusion (the passive spread of information) was added into the dissemination sub-domain. The sub-domain was renamed '*dissemination & diffusion*'.

Due to the complex nature of the institutions domain, an additional SME, SME34, was contacted after the second round of verification interviews to verify the revised institutions sub-domain. SME34 is based in South Africa and is an expert in public law. During the interview, SME34 confirmed that it was necessary to make provisions for meso- and micro-community level laws & regulations. SME34 gave the example of South African customary law and traditional councils, which are recognised under the Constitution; however, these laws and councils must still abide by the laws outlined in the Constitution. While there should be synergy between the customary laws, traditional councils and the Constitution, the state does not always provide sufficient oversight, leading to some practices not conforming to what is outlined in the Constitution. Further, SME34 agreed that the policies sub-domain should be separate from the laws & regulations sub-domain, explaining that laws & regulations speak to mandatory legislation, whereas policies are more aspirational in nature.

8.4.1.2 Second Verification Interviews: Health System Levels

The feedback given by the SMEs, where specific refinements were suggested to the health system levels, is discussed in Table 8.8. A detailed discussion of the verification results pertaining to the health system levels is presented in Appendix I, Section g).

Table 8.8: Second verification interview – SME feedback on the health system levels dimension

Level	SME feedback	Discussion
Micro-level	SME15 suggested that the terminology for micro-facility level be adjusted to improve understanding of what the level encompasses.	The micro-facility level was renamed 'micro-provider level' to improve the user's understanding of the levels. This refinement improves the transferability of the maturity model to different LMIC settings.
Importance of different health system levels	SME16 stated that not all levels would have equal importance in improving the success of the implementation process.	To ensure that the user of the maturity model is aware that the different health system levels will not necessarily have the same impact on the implementation process, statements addressing this were included in the operationalised maturity model.

8.4.1.3 Second Verification Interviews: Maturity Levels

All SMEs agreed that maturity levels are an appropriate method of assessing implementation. SME27 discussed the improvement process that maturity models enable, "*I really love your maturity, dimension, and levels, and people have somehow struggled to bring in that … optimisation piece into all these domains*". The feedback given by the SMEs, where specific refinements were suggested to the maturity levels, is discussed in Table 8.9.

Table 8.9: Second verification interview – SME feedback on the maturity levels

Level	SME feedback	Discussion
Order of maturity levels	SME17 questioned whether level 0 should be less optimal than level 1.	The order of the maturity levels was re-visited to determine whether they needed to be adjusted. The standard definition for maturity level 0 is: *does not exist* and for level 1 is *ad-hoc or chaotic processes* (CMMI Product Team, 2002). Both maturity levels 0 and 1 are sub-optimal; thus, maturity levels 0 and 1 were kept the same and coded using the same colour in the operationalised maturity model.

8.4.1.4 Second Verification Interviews: General Discussions and Suggestions

The feedback given by the SMEs, where general refinements were suggested to the maturity model, is discussed in Table 8.10.

Table 8.10: Second verification interviews – SME feedback on the usability and usefulness of the maturity model

Aspect	SME feedback	Discussion
Overview	Referring to the overview sheet, SME8 recommended that the infographic showing the implementation domain should be more self-explanatory.	Text boxes defining each domain were included in the overview infographic to refine the overview sheet's infographic.
Structure	SME20 and SME22 discussed how the maturity model was presented linearly, whereas implementation processes tend to be more circular.	To ensure that the maturity model can be used in a more circular manner, the domain numbering was removed, and a navigation overview of the implementation domains and sub-domains was inserted at the start of each domain, allowing the user to jump between domains. On each user interface sheet, there are index buttons that the user can easily use to navigate to different domains and sub-domains.
General considerations	SME27 suggested including a section where the user maps the process involved when using the innovation.	In the general considerations user interface, an additional section was included. The user is prompted to map the process followed when using the innovation, including (i) who is using the innovation, (ii) how they are using it, (iii) where it is being used, and (iv) what happens before, after and during use.
Use cases	SME7, SME12 and SME25 recommended specifying where the different domains would be applicable in the implementation process or the innovation life cycle.	In the introductory section of each domain, the different use cases of the maturity model (which would include designing an innovation, searching for an innovation, preparing for implementation, inter-implementation, post-pilot, sustainment, and unsuccessful implementation) are discussed.
Results interpretation	SME22 discussed the likelihood that different users assessing the same scenario would return different results. In addition, SME26 suggested standardising the metrics used to evaluate the performance of the different domains should be considered to standardise the results.	Data sources will likely include a mixture of quantitative and qualitative data collection techniques to assess a domain effectively. The specific data sources will depend on the scenario being assessed and the resources available to the user. For each sub-domain, examples of data sources that can be used to collect data are provided. There is an inherent bias that comes with qualitative assessments (Galdas, 2017); furthermore, it is difficult to standardise qualitative metrics, especially when the maturity model needs to be applicable to a range of innovations and LMIC contexts. Therefore, standardised metrics were not included, as this would limit the transferability and flexibility of the maturity model; instead, it is recommended that a variety of data collection techniques be used when completing the maturity assessment.
Results interpretation	Both SME7 and SME27 suggested matching specific implementation improvement strategies to maturity scores for each sub-domain.	The researcher agrees that this would be a good addition to the maturity model; however, this falls outside the study scope. Nonetheless, general implementation strategies were included at the end of the assessment process to assist users with developing improvement processes. Additionally, on each results page, a text box was included with a general discussion on how to improve a maturity score.

8.4.2 Refinements Based on the Second Verification Interviews

The feedback given by the SMEs during the second verification interviews was used to refine the maturity model further. Table 8.11 summarises the modifications made to the maturity model during the second set of verification interviews. The modifications made are linked to the interview results presented in Section 8.4.1.

Table 8.11: Summary of the refinements made after the second verification interviews

No.	Component(s)	Refinements	Refer to
1	Innovation sub-domain: Type	Merged with actors sub-domain: Beliefs & attitudes.	Table 8.7
2	Innovation sub-domain: Evidence strength	Changed to: Supporting evidence.	Table 8.7
3	Innovation sub-domain: Ethics	Changed to: Ethical & equity.	Table 8.7
4	Innovation sub-domains: Ethics; Design Resources sub-domains: Physical; Financial Institutions sub-domains: Political priorities; Regulatory system; Policies; Standards & guidelines Relations & networks sub-domains: Relationships & leadership; Collaborations; Evaluation, feedback & communication Knowledge sub-domain: Education Actors sub-domains: Culture; Beliefs & attitudes	Adjusting definitions/descriptions/guiding questions.	Table 8.7
5	Resources sub-domain: Physical	Changed to: Infrastructure, services & physical resources.	Table 8.7
6	Institutions sub-domain: Political context & priorities	Changed to: Institutions & priorities.	Table 8.7
7	Institutions sub-domain: Regulatory system	Changed to: Laws & regulations.	Table 8.7
8	Knowledge sub-domain: Dissemination	Changed to: Dissemination & diffusion.	Table 8.7
9	Knowledge sub-domain: Education	Changed to: Education & training.	Table 8.7
10	Actors sub-domain: Motivations, incentives, disincentives	Changed to: Motivations.	Table 8.7
11	General considerations user interface	Sections included to enable the specification of the challenge or gap being addressed by the innovation and for the user to map the process followed when using the innovation.	Table 8.7 Table 8.10
12	Health system levels	Micro-health facility level was changed to: Micro-provider level.	Table 8.8
13	Maturity levels	Maturity levels 0 and 1 are deemed as sub-optimal and thus coded using the same colour.	Table 8.9
14	Introductory tabs	Text boxes were included to improve understanding of the overview infographic.	Table 8.10
15	Overall maturity model	The ability to not assess every sub-domain or health system level was included; Statements on the different sub-domain weightings were included; A discussion of the different use cases was included for each domain; The data sources that could be used to complete the sub-domains were incorporated;	Table 8.7 Table 8.8 Table 8.10

Table continues on next page

Table continued from previous page

No.	Component(s)	Refinements	Refer to
		The domains were reordered, and the linear numbering was removed; A discussion on how the maturity scores can be improved was included on each results page; and, General implementation improvement strategies were included at the end of the maturity model.	

In addition to the refinements made from the second set of verification interviews, the researcher used insights from the interviews to make three additional refinements to the maturity model. The first refinement was to merge two overlapping innovation sub-domains, 'Design' and 'Functionality'. These innovation sub-domains were merged because it is difficult to delineate and separately assess them. The design of the innovation is directly related to the innovation's functionality. How the innovation is designed predisposes the functions that the innovation will have. The remaining two refinements were adjustments to sub-domain naming conventions to improve clarity. The 'Relationships & leadership' sub-domain was renamed to 'Relationship dynamics', and the 'Evaluation, feedback & communication' sub-domain was renamed to 'Evaluation networks'. The naming conventions of the two sub-domains were simplified to improve the clarity of what the sub-domains are assessing and to ensure that the sub-domains are not confused with other sub-domains.

After the second set of verification interviews, the refinements spanned all three dimensions of the maturity model. Only two structural refinements were made, i.e., merging the type sub-domain with the beliefs & attitudes sub-domain; and merging the functionality sub-domain with the design sub-domain. No structural refinements were made to the maturity levels or health system levels. The rest of the refinements were enhancements to improve the clarity of the maturity model, which included refining naming conventions, definitions and descriptions. The refined implementation domains and corresponding subdomains are displayed in Figure 8.5.

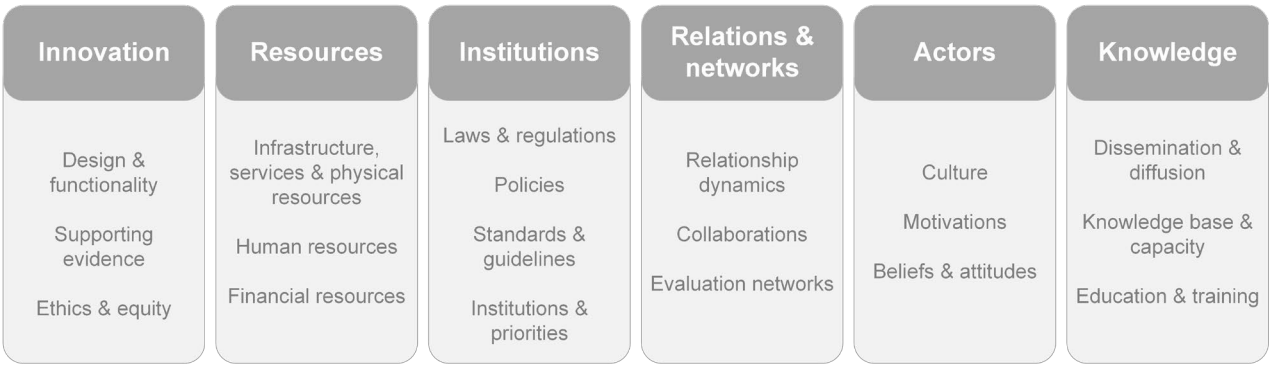

Figure 8.5: Refined implementation domains and sub-domains after second verification interviews

8.5 REVISITING THE VERIFICATION OBJECTIVES

This section establishes the extent to which the verification process fulfilled the evaluation objectives presented in Section 2.3.3 of Chapter 2. This is done by reflecting on the two verification specific evaluation objectives: (i) theoretical verification and (ii) structural verification.

8.5.1 Theoretical Verification

It was necessary to verify the model's content by gaining insights from experts with practical experience implementing innovations in LMIC health systems because the model was developed through inductive reasoning. During the verification interviews, SMEs analysed the model's content providing suggestions on how to refine its content, in terms of its applicability to the LMIC context and its effectiveness at encompassing relevant barriers and enablers to implementation.

SME recommendations were incorporated to ensure that the model had been built correctly, according to the requirement specifications outlined in Chapter 5. In addition to refinement suggestions, SMEs verified the model's content by considering the model in relation to their own experiences with innovation implementation. The SMEs agreed that the model's content applies to an LMIC context and holistically assesses an implementation process. It can thus be concluded that the model's content is verified.

8.5.2 Structural Verification

The SMEs evaluated the model's structure to determine whether it fits its intended purpose as described by the functional requirements (refer to Section 5.1.1), i.e., to assess a system's capability to implement an innovation and to define a maturation path. The SMEs were satisfied with the model's structure and did not propose any major structural refinements. SMEs agreed that the combination of maturity levels and levels of analysis is an effective structure for achieving the model's intended purpose. Furthermore, the SMEs reflected on the usability provided by the structure; they concurred that the model's structure is understandable, although this understanding might differ depending on the user's skills. In addition, the practical insights gained while performing the verification case study were used to refine the maturity model further; the refinements resulting from the verification case study were focused on further improving the maturity model's usability and to improve the understandability of the model's structure. Thus, it can be concluded that the model's structure is verified.

8.6 CHAPTER 8: CONCLUSION

This chapter describes the process followed to verify the preliminary maturity model's content and structure. The verification process consisted of interviews with SMEs and a case study, which were used to refine the maturity model iteratively and theoretically and structurally verify the model, resulting in the final maturity model – the HII-MM. The second phase of the evaluation process, validation, is described in the next chapter.

Chapter 9 HII-MM Validation

In the previous chapter, the first part of the evaluation process was presented, in which the HII-MM's structure and content of the were verified for their theoretical integrity. This chapter presents the second section of the evaluation process, and the HII-MM is validated. Validation is used to describe whether "*a measure of a concept really measures the concept it is intended to measure*" (Bryman and Bell, 2011, p.174); in the context of this study, validation is done to ensure that the HII-MM is relevant, useful and usable. The process followed to validate the HII-MM consists of validation interviews with subject matter experts (SMEs) and two case studies.

Chapter 9 Outline:

9.1 VALIDATION METHODOLOGY

Figure 9.1 shows the process followed to evaluate the HII-MM and ensure that it meets the requirement specifications. During the validation stage of the evaluation process, the HII-MM's relevance, usefulness and usability are investigated through interviews and case studies. The objective of the validation process is not to identify additional refinements, as this was completed in the verification process of Chapter 8 (Chp. 8), but to validate that the HII-MM meets the requirement specifications defined in Chapter 5. Details of the verification methodology are described in Chapter 2, Section 2.3.3.

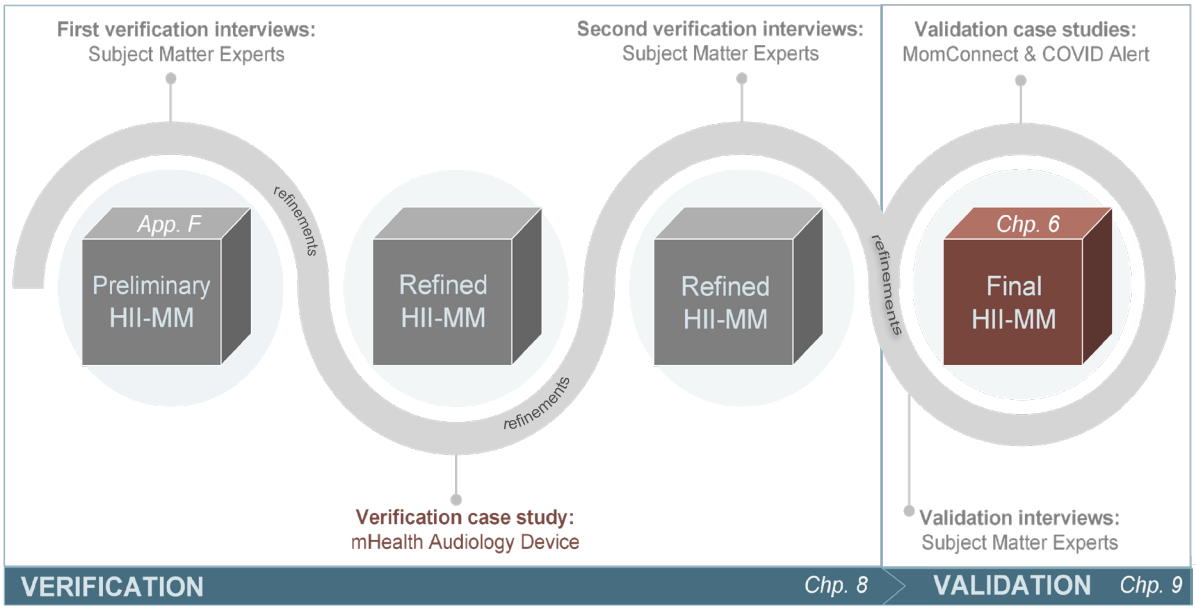

Figure 9.1: Maturity model evaluative phase – validation

9.2 VALIDATION INTERVIEWS

The validation interviews are undertaken to meet RO.3, defined in Chapter 1, Section 1.4, and more specifically to address sub-objective RO.3.2, which states the need to *receive inputs from subject matter experts to validate the relevance, usefulness, and usability* of the HII-MM. Thus, the validation interviews were used to validate the HII-MM's relevance, usefulness, and usability.

9.2.1 Validation Interview Methodology

The basic interview protocol followed throughout this study is detailed in Chapter 2, Section 2.3.3.1. The protocol consists of five overarching parts (i) interview outline, (ii) demographic questions, (iii) introduction to the HII-MM, (iv) detailed description of the HII-MM, and (v) interview questions.

The guiding presentation for the validation interview was incorporated into the HII-MM Excel workbook (described in Chapter 7). The presentation is depicted in Appendix I, Section I.3. The questions asked during the validation interviews were developed using the pre-defined functional requirements (described in Section 5.1.1), user requirements (described in Section 5.1.2) and the study aim (described in Section 1.3). Interviewees were requested to reflect on the HII-MM's relevance, usability, and usefulness. The interviews were used to validate the HII-MM's:

i. Ability to provide a holistic assessment of a health innovation landscape (FR1, FR2);
ii. Applicability to the LMIC context (FR3, study aim);
iii. Transferability between LMICs (study aim);
iv. Flexibility among different health innovations (study aim);
v. Usefulness as a decision support tool for informing change, benchmarking, assessing implementation capability (UR2, UR3, FR4, UR4); and,
vi. Usability and user-friendliness while maintaining an adequate level of complexity to assess implementation in a health innovation system (UR1).

The verification case study, which was performed on a mHealth innovation in South Africa (refer to Chapter 8, Section 8.3), was used to guide the detailed description of the HII-MM. By using the South African setting to guide the HII-MM's description, SMEs could reflect on its transferability to their geographic areas of expertise. Furthermore, using the mHealth audiology device to provide a detailed description of the HII-MM allowed the SMEs to reflect on its flexibility to the range of innovations with which they have experience.

9.2.2 Conducting the Validation Interviews

The validation interviews were conducted with 27 SMEs (SME7 to SME33). The criteria for an SME to be included in the study include: (i) relevant experience in one or more LMICs; (ii) experience with health and/or innovation systems; and (iii) knowledge of health innovation(s). SMEs with expertise in a range of LMICs were invited to participate in the study to ensure that the HII-MM meets DR2, which specifies that the HII-MM *must be applicable to a broad range of LMIC contexts*. Figure 9.2

shows the distribution of country income levels represented by the SMEs who participated in the validation interviews. All three income levels within the LMIC classification are covered[16].

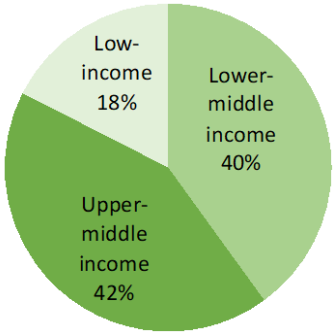

Figure 9.2: Distribution of country income levels covered in the validation interviews

The geographic regions covered by the SMEs who participated in the validation interviews are shown in Figure 9.3. It should be noted that numerous SMEs had expertise in more than one country (see Table 9.1). The interviewees' expertise covers 25 countries and seven geographic regions[17].

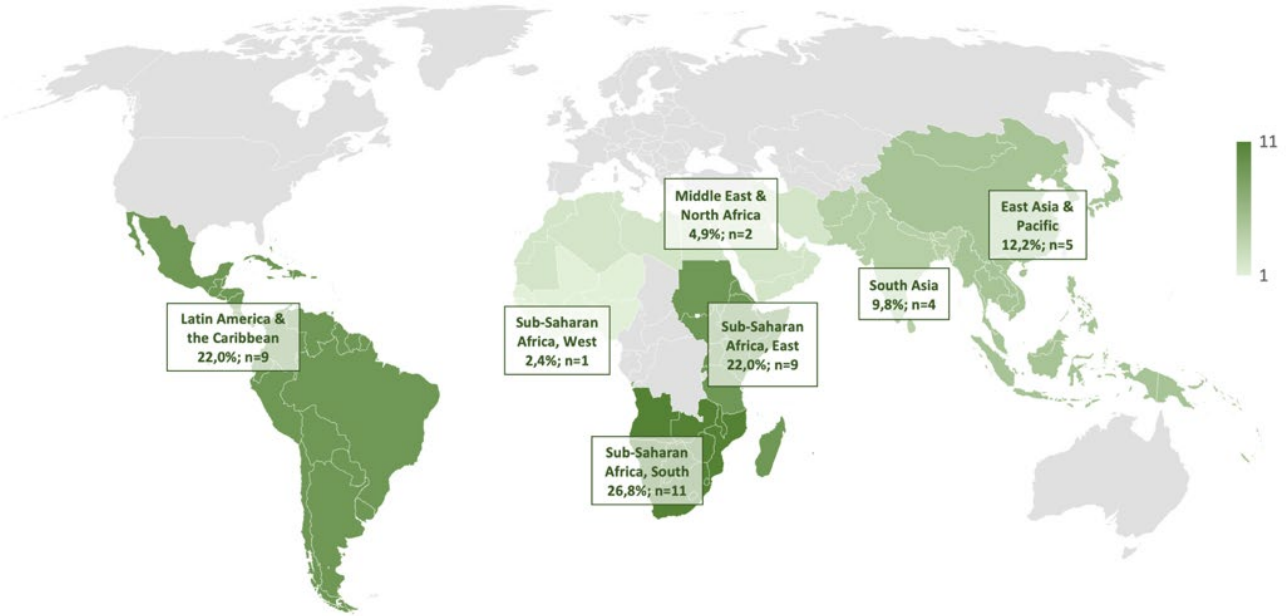

Figure 9.3: Number of SMEs who have expertise in a geographic region

The specific innovations that interviewees have experience with are described in Table 9.1. As highlighted by the third column of Table 9.1, the SMEs interviewed have a wide range of innovation

[16] The income levels are defined by The World Bank (2021) according to a country's gross national income. In 2020, of the total LMICs (n=137), low-income countries made up 19,7% (n=27); lower-middle-income countries made up 40,2% (n=55), and upper-middle-income countries made up 40,2% (n=55) (The World Bank, 2021a).

[17] The countries are classified according to the geographic regions defined by The World Bank (2021), which classifies countries into seven regions, namely (i) East Asia and Pacific; (ii) Europe and Central Asia; (iii) Latin America and the Caribbean; (iv) the Middle East and North Africa; (v) North America; (vi) South Asia; and (vii) Sub-Saharan Africa. Sub-Saharan Africa was further divided into regions defined by the African Union (1976), namely (i) West, (ii) East, (iii) Central, and (iv) South. The North American region consists of no LMICs; thus, no experts were sought from this region; attempts to identify experts from Central Sub-Saharan Africa, Europe and Central Asia were unsuccessful.

implementation experience; this is congruous with validating that the HII-MM meets DR1, which stipulates that the HII-MM should apply to *a variety of evidence-based health innovations.*

Table 9.1: Innovation implementation experience of the SMEs participating in the validation interviews

Subject Matter Expert	Countries of expertise	Innovation implementation experience
SME7	Nigeria, Tanzania	Vaccinations and immunisation programmes. Short Messaging Service (SMS) intervention to educate and inform parents and the public about the importance of vaccines to improve vaccine uptake.
SME8	South Africa	TB and HIV treatment programmes and primary care.
SME9	Zimbabwe	Roll out of non-pneumatic anti-shock garment for postpartum haemorrhage; vaccination.
SME10	South Africa	Health policies; eHealth; electronic intensive care unit.
SME11	Malawi	Electronic medical records; eHealth.
SME12	South Africa	Health information systems.
SME13	South Africa, Zimbabwe	Health procedures, including the implementation of voluntary male circumcision and HIV self-testing; malaria interventions.
SME14	Tanzania, Ethiopia	Pharmaceuticals; procedures; treatments; delivering healthcare to vulnerable populations; HIV care interventions.
SME15	Zambia, Madagascar	Diagnostics for HIV; diagnostics for cervical cancer; new drugs for HIV; new ways of delivering services at the health centre level.
SME16	South Africa	Frugal innovation for surgical care.
SME17	Pakistan	Innovative digital tools; the sustainability of TB control programs.
SME18	Thailand	Maternal health interventions; reducing the overuse of caesarean sections.
SME19	South Africa	Mental health policies for children and adolescents; access to mental healthcare services.
SME20	India, Zambia	Community-based health programs and processes; maternal and newborn health interventions.
SME21	China, Vietnam	Smoking cessation intervention; social media-based health promotion intervention.
SME22	Vietnam, India, Myanmar	Self-management tool for people with depression; HIV/AIDS prevention programs; mental health programs; maternal child health interventions; healthcare for ethnic minorities.
SME23	Bolivia	Sexual and reproductive health interventions; nutrition for children and adolescents.
SME24	Sudan	Health policies.
SME25	Uganda	Cardiovascular disease program.
SME26	Lebanon	Tele-mental health innovation.
SME27	India	Integration of mental health and primary care; culturally rooted interventions for mental health.
SME28	Brazil, Columbia	Community-based physical activity programs; community-wide policy interventions.
SME29	Jordan	mHealth and telehealth.
SME30	Columbia, Mexico, Peru	Health promotion in primary health centres.
SME31	Mexico	Health policies for non-communicable diseases; physical activity and nutrition as an intervention at the primary healthcare level; preventive medicine.
SME32	Mexico	Health policies for non-communicable diseases; physical activity and nutrition as an intervention at the primary healthcare level; preventive medicine.
SME33	Uganda, Kenya, Rwanda	Maternal and neonatal health programs, health facility improvement.

9.2.3 Validation Interview Outcomes

In the following sections, the validation interview results are discussed. The results are structured according to the three validation outcomes (i) relevance, presented in Section 9.2.3.1, (ii) usefulness, presented in Section 9.2.3.2; and (iii) usability, presented in Section 9.2.3.3. In addition to the three validation outcomes, results from the general discussions on the HII-MM's uniqueness are described in Section 9.2.3.4.

9.2.3.1 Relevance

The first set of questions asked during the validation interview aimed to validate the relevance of the HII-MM. To do this, SMEs were asked to reflect on: (i) the HII-MM's ability to provide a holistic assessment of an LMIC health system; (ii) its applicability to the LMIC context in which it is supposed to be applied; (iii) whether the HII-MM offers an adequate level of complexity for assessing implementation; (iv) the HII-MM's transferability to different LMIC contexts; and (v) the HII-MM's flexibility to assess different types of innovations.

i) Provides a Holistic Assessment

The SMEs agreed that the HII-MM provides a holistic assessment of an LMIC health system. There was consensus that it is important to include all the aspects present in the HII-MM; SME7 commented, "*I don't think any components should be removed because they encompass everything we are looking for.*" SME15 added, "*you have most of the major components, … you've thought through all the different aspects of a health system.*"

SME21 contemplated the comprehensiveness of the HII-MM, "*this is really a comprehensive; some of the components you mentioned that I have never thought about it before.*" Additionally, SME31 discussed the potential disadvantage of the HII-MM's comprehensiveness, "*It's … very holistic because it goes [through] everything….*"

Discussing the components of a health system, SME8 commented, "*I think the way you unpacked what a health system is … it's not just the world health building blocks, which mostly focusing on infrastructure. It has to do with the people … who make up the health system, which includes the patients and the health workers and managers and people at every level… that is very important because … if you don't understand the people who make up and those relationships, then, I don't think you really have a grip on the health system.*"

When considering the HII-MM's ability to allow for variability, SME14 observed, "*It would be a nice comparison tool and allows for variability and for one to understand what is going on in the system in a comprehensive way.*"

ii) Adequate Level of Complexity

When considering the HII-MM's level of complexity, SMEs agreed that the HII-MM does contain an adequate level of complexity for assessing implementation; however, there were observations that the level of complexity would make the HII-MM time-consuming to complete. SME23 remarked that "*I think it is complex, [it's] not easy, but … rather clearly [shows] what you need to get the information*."

SME14 commented that the HII-MM "*seems pretty usable, as everything is defined, seems easy enough to do. The complexity is what is good and what is difficult about it – it makes it comprehensive, but it also makes it difficult to get through*". SME15 further contemplated the balance between complexity and the time taken to complete the assessment, "*you don't want it to become too complex because then, people won't want to use it … you want it to be simple enough that it gets used and doesn't take forever to learn how to use it because then that's a barrier … it seems like you have a lot in there, but it's pretty straightforward, and you've done a nice job defining what you mean … the way you've set it up is, is very clear and easy to follow*."

While the complexity of the HII-MM might be a barrier to use, this level of complexity is necessary to assess a complex dynamic system. As SME32 remarked, "*I believe [it's] a good model because it [is]... holistic … you realise that it's very complex to take into account all this, but if you want something to work, you have to have all this*."

iii) Applicable to LMIC Context

The SMEs agreed that the HII-MM is appropriate and applicable to an LMIC context. With representation from 25 different LMICs, the HII-MM's applicability to the LMIC context was validated. SME11 commented that "*This [model] looks at the key aspects that someone in [an] LMIC should consider when implementing an innovation… The model would be able to expose the gaps that are in a system. Because I have worked in this area for four years, I know this model can be implemented and is very applicable.*"

Reflecting on their experience in Tanzania, SME14 stated, "*In Tanzania [it] would be applicable because we were dealing with a lot of national level policies … that affected the implementation of healthcare interventions. The program was very much affected by stigma surrounding drug use and perceptions of drug use, which is why education was important and interpersonal relationships, as this influenced the healthcare that people were getting. This would be useful to compare innovations across settings, even within the same country but at different facilities, to compare where there are deficits in each setting and to have a more comprehensive way to understand the challenges or shortfalls*."

The inclusion of culture was highlighted as a vital component of the LMIC context, with SME7 remarking that the HII-MM "*is applicable… because I like the fact that you brought in the cultural aspects, using Africa, for example, we are culturally centred people… I like the fact that this model also acknowledges those contextual factors that can contribute to accepting or rejecting an intervention*". SME31 discussed the strength of the domains included in the HII-MM being specific to the LMIC context "*one of the strengths of this tool is that the includes things and domains that others don't include, which are very important in low- middle-income countries, such as culture, such as this dissemination, such as viewpoint of actors. It will be … very useful in this situation because most of the tools that I know [are] not related with low-income countries."*

iv) Transferability

As described in Section 9.2.1, the verification case study, which had been performed in the South African setting, was used to provide a detailed description of the HII-MM—having described the HII-MM's usability from a South African perspective allowed for the transferability discussion. Hence, the SMEs were requested to consider the transferability of the HII-MM to different LMIC health systems. Perspectives were received from 25 different countries (see Section 9.2.2), and from their

experiences in these countries, SMEs agreed that the HII-MM would apply to the countries where they had expertise. SME26 agrees that it would be transferable because "*it takes into consideration the main cornerstones of health systems.*"

Contemplating the transferability of the HII-MM in terms of the similarities that exist between different systems, SME15 observed that "*there are so many similarities between countries actually, though, of course, they're different, they've got different, you know, politics and things going on, but a lot of them do have some of the same challenges... And every human system, in a way, is designed in a similar fashion. And so, I do think … it would be quite transferable between countries.*" When discussing the transferability of the HII-MM, SME28 noted that "*if you will translate this into other languages, maybe have it looked at by native speakers and making sure that the terms translate in the way that they should*."

SME14 discussed the HII-MM's transferability to different settings within a country, "*A lot of my experiences in East Africa are that the clinics are all very different from each other, so even going from province to province, you will find differences that will affect your ability to deliver healthcare services. This would then be useful because you would be able to assess all of that at once – then you can assess why something is working in one province and not another due to x, y, z reasons*."

SME21, SME24 and SME15 considered transferability concerning the HII-MM's ability to be modified. SME24 agreed that the HII-MM is transferrable "*because it can accept modification*." SME15 commented that "*the tool is, is flexible enough that you can then define… what you mean when you're referring to the sub-national level, or maybe you could even have the meso- be the state and then have the, you know, the, the towns be the next level … the user can play around with it*." Discussing how the HII-MM might be adapted to settings, SME21 stated, "*when you use this model in different countries … you need local people to help with the adaptation*."

Some of the SMEs who were interviewed during the validation process also had experience in HICs. SME12 remarked that the HII-MM would be transferrable to HICs where the impact that a community's culture could have on the implementation process is often neglected. SME17 discussed their experience with the health system in England, stating, "*I would say it's… also transferable to high-income countries… with just a little bit of tailoring*." Additionally, SME22 reflected on the HII-MM's transferability, "*I would say it's as relevant in India and Vietnam and Canada as it would be in South Africa.*"

v) Flexibility

The SMEs were asked to reflect on the HII-MM's flexibility to be applied to different evidence-based health innovations. Some SMEs remarked that with certain innovations, not all sub-domains or health system levels would be relevant. The HII-MM can still cater for this by enabling the user to exclude the levels or sub-domains perceived as irrelevant to the innovation.

Discussing the HII-MM's flexibility, SME19 remarked, "*it's not narrowed down to specific interventions; it … could accommodate different kinds of health system interventions. That makes it unique, and that makes it a great tool*." SME7 agreed that the HII-MM is flexible because "*it touches every part of what is involved in implementing an intervention or even sustaining it*."

When reflecting on the different innovations that SME8 had been involved in implementing, SME8 commented, "*thinking of a handful of things that I've worked on that are all quite different from each*

other, you know, from ARV treatment, which is a massive programmatic implementation to smaller scale innovations. And I can definitely see how it can be applied in each case." SME13 also discussed the HII-MM's flexibility in terms of their experiences, "*as you were going through the whole [model], I [was] trying to think about the [HIV] self-screening… the malaria programs… [medical] male circumcision. So really, I think you can apply [the model to different innovations]*."

9.2.3.2 Usefulness

The second set of questions asked during the validation interview (refer to Appendix I, Section I.3 for the validation questions) aimed at validating the usefulness of the HII-MM. To do this, SMEs were asked to reflect on the HII-MM's ability to (i) add value to stakeholders; (ii) be used as a benchmarking tool; (iii) enlighten stakeholders; (iv) inform change and guide improvement initiatives; and (v) to be useful in practice.

i) Value-Add

When discussing whether the HII-MM would add value to stakeholders involved in implementing evidence-based health innovations, SMEs concurred that the HII-MM would be valuable. SME9 viewed the HII-MM's ability to "*conceptualise and consider all areas*" as its value-add. SME16 commented that the HII-MM "*definitely adds value to stakeholders by providing a 360 analysis of the innovation and by making clear its weaknesses and strengths in different domains.*"

SME15 commented on the HII-MM's ability to identify challenges, "*it can help to flag … challenges, like we're all set for everything except for the communication, or we're all set, except for, we don't have people trained to use this. For the implementers, it does help to kind of pinpoint those things, which really may be obvious … but it's always helpful to have gone through a process like this.*" SME14 considered the value of the HII-MM in terms of its benchmarking ability, "*it would be a good overview to easily make comparisons, so that would be valuable.*"

Reflecting on a previous pilot where the HII-MM could have added value, SME10 stated, "*It'll definitely give them a direction… the pilot, what we did failed miserably because there was not a structured approach*." When contemplating the value-add that the HII-MM could have in terms of projects, SME8 stated, "*In my experience of some of the projects that I've worked in, I think it would be hugely valuable, to even be able to quantify things in the way that your model does… I'm not aware of a framework or model that addresses things in the same way this model does … in terms of piloting something or even thinking of an existing innovation and being able to quantify and… I'm even thinking [of the] … TB preventive therapy [intervention that was] very poorly implemented... we recently did a review, in various facilities across the country… there's so many issues and not all of them can be addressed, but I think a model like this will help to actually identify what are key things that we can do… at least achieve some level of success.*"

ii) Benchmarking

It was agreed that the HII-MM is useful for benchmarking. SME20 commented, "*it makes sense to be able to compare, especially if you had the spider diagrams, they're very visual, and you can compare the different ones across*." SME26 also highlighted the benefits of the radar charts, "*I like … the visual representation with the radar chart, and I can see how, it could be even, an online tool, where people want to see how their program is doing in terms of this… I can totally see it as it's a benchmarking tool*."

iii) Enlighten Stakeholders

The SMEs agreed that the HII-MM could be helpful in enlightening stakeholders and their ability to select an innovation, understand and identify gaps, or understand what went wrong in an implementation process. SME7 highlighted the HII-MM's ability to identify gaps, "*if you're addressing all those questions at each level, it helps you identify where there's a gap at each level.*" SME9 discussed how the tool could be used to enlighten donors who fund innovations, "*It would be [a] really good, donor reporting tool, those [radar] diagrams are really good because they paint a really clear picture really quickly of what's happening*." SME16 remarked on how the HII-MM may enlighten stakeholders, "*Definitely enlighten stakeholders by allowing for informed and critical analysis of the innovation and the whole ecosystem in which it is embedded*."

SME20 discussed the HII-MM's ability to enlighten stakeholders by encouraging systems thinking, "*understanding and identifying gaps, it makes sense to understand what's actually needed or what would really benefit the system … this definitely gives more insight and makes you think more of the system as a broader concept … often stakeholders might just be focused on one thing*." SME8 also discussed the enlightening nature of the systems thinking view, "*being able to visualise, all the things that go into implementing an innovation in this way … it actually becomes a little bit obscure, because people take it for granted. So, I think when a person is implementing, you can actually lay the entire landscape of all the things that influence whether something will have an impact ultimately [which] is enlightening*."

iv) Inform Change and Guide Improvement Initiatives

The SMEs agreed that the HII-MM could be used to inform change or guide improvement initiatives. There were discussions around the HII-MM not providing specific suggestions for improvement. The HII-MM does not provide explicit improvement processes, as discussed in Sections 7.5 and 8.4.1.4; however, the maturity levels offer an evolutionary path to a more optimal state. While the HII-MM does not provide specific improvement suggestions, a user should be able to use the HII-MM to inform change and guide improvement initiatives, developing context-specific improvement processes.

SME16 commented that the HII-MM "*makes explicit what is good or bad but does not necessarily provide a theory of change or way to navigate the improvement or adoption of innovation journey.*" SME15 observed, "*Obviously, the model itself won't solve everything, but at least it can inform what needs to change.*" SME8 discussed how the HII-MM could be used to inform change, stating, "*because you'd be aware of specific weaknesses and how they may have formed … you could do quality improvement projects and initiatives around specific aspects in the health system or on your innovation.*" SME21 commented that the HII-MM "*can be very helpful for the stakeholders if they want to improve their intervention or the system.*"

v) Useful in Practice

It concurred that the HII-MM would be useful in practice. SME23 commented that the HII-MM "*will be very useful in practice…I think it is clear…very useful to collect information*." The concerns around the time taken to complete the assessment were raised by SME14, who commented that the HII-MM "*seems useful; my only thing is that it seems like it would potentially take a lot of time to complete. It has been my experience that people tend to not have the time to do these more in-depth assessments, and people will come in and do it for them, which has its weaknesses*." As discussed

in Section 9.2.3.1ii), there is a delicate balance between ensuring that the HII-MM is adequately complex, capturing the nuances of an implementation process, and simple enough to use. As discussed by SME15, the HII-MM could save stakeholders a lot of time and money in the long term, "*often we all might tend to run ahead without having really gone through a process like this. So, I do think having a conceptual framework like this is, could be very useful and actually would benefit people and probably save lots of time and money and effort.*"

SMEs considered different reasons why the HII-MM would be useful in practice, with SME13 discussing the optimal use of resources, stating, "*resources are limited in [LMICs], [you] don't want to send out something that… down the line you realise we've spent billions, but it's not working… So [the model] should be [used] as early as possible into the trial phase [so] that we [can] make changes.*" SME19 commented on the general use for all organisations involved in implementing evidence-based health innovations, "*I think the framework is actually a very brilliant one… every organisation … setting out to implement an intervention in the community should actually consider having [it]. It's an intervention that should guide you from … the very beginning where you design or conceptualise your intervention to the actual implementation, …[and] evaluation of the intervention.*"

SME19 discussed the HII-MM's usefulness in terms of ensuring an innovation is needs-based and equitable, stating, "*it's a very interesting model that would assist program implementers … one of the major challenges that I have identified, with designing and implementing interventions, is a general way of structuring the interventions such that you're sure that this intervention is addressing the needs that it was deciding to address. And then the services are reaching the population, the target population.*" SME7 also commented on the HII-MM's usefulness in that it highlights ensuring that the innovation is needs-based and acknowledges culture, "*one thing I really like about this [model] is it [goes] deeper … I'm always going towards the cultural piece, and it's based on these two innovations that I have coordinated, and I've seen how, designing interventions to the needs of the people, acknowledging that culture can either promote acceptability or rejection of intervention*."

Reflecting on their experiences, SME11 stated, "*I have done an analysis of eHealth in Malawi, and this could be used in my context while you were taking me through the model I could relate, and this model could be used overall*." SME26 confirmed the HII-MM's practical usefulness, commenting, "*I will definitely love to know how it goes and when you get publications, send them my way. And I would definitely use this when it's available*." SME11 also stated that they would use the HII-MM "*I am looking forward to [seeing] it being adopted. Once you have published it, I would use it to assess something to determine whether there are gaps; it does cover a lot of the aspects that we look at. Some of the other models only look at how the system is performing, and they do not look at, e.g., are there policies to support those … this one really looks at all of the aspects.*" Additionally, SME28 commented, "*what I like about your model is that it's like super straightforward. You can clearly assign a number, and the radar charts [are] very visual. So, you can see where you're lacking…I really like it, honestly … once you get this going, I will probably use it for my programs*."

9.2.3.3 Usability

The third set of questions asked during the validation interview was aimed at validating the usability of the HII-MM. To do this, SMEs were asked to reflect on (i) how understandable the layout of the HII-MM is; and (ii) how user-friendly the HII-MM is.

i) Layout Understandable

Generally, the SMEs agreed that the layout of the HII-MM is understandable, although this understanding might differ depending on the user's skills. SME7 commented that "*the layout is understandable … but this again depends on the level of the program managers. So, which boils down to building capacity on how to use this model.*"

SME13 noted that "*there's a whole lot of explanations to it for every domain and every sub-component of the domain. So, it's very easy to know what … you are measuring.*" Reflecting on the HII-MM, SME11 commented, "*I have been able to follow and understand it in this short period of time; this makes me feel like it is great and might be simple to use.*"

ii) User-Friendly

When contemplating how user-friendly the HII-MM is, SMEs noted that the HII-MM is user-friendly, with SME29 commenting that the HII-MM is "*very understandable and user-friendly.*" However, there were suggestions to provide a simplified version of the HII-MM to increase its reach. SME10 stated that it is "*definitely going to help in the academic side, but on the service industry side … you might have to structure it in such a way that you people will not lose interest halfway through*." The suggestions to create a simplified version of the HII-MM will be considered in future work. SME19 added that "*it's a very brilliant idea and very useful. What I think you should also consider is making it as simple as possible*."

Reflecting on the user-friendliness of the HII-MM, SME15 observed that they could "*understand the flow [of the model], and I felt like you had some nice visuals in there, and you had [an] arrow to link to different [interfaces] … so for me it was intuitive*." SME7 considered the descriptions provided throughout the HII-MM, "*I think it's user-friendly, especially for the fact that it also provides [a] description on … what [a] domain is about and the questions ... So having those descriptions were user-friendly for me*."

9.2.3.4 Uniqueness

The last set of questions asked during the validation interview was aimed at validating the uniqueness of the HII-MM. Generally, SMEs were aware of models that assess implementation processes; however, these models were described as higher-level assessments, not providing sufficient detail, and no SME was aware of a model specific to the LMIC context. SME16 commented, "*I'm not aware of any other model specifically focusing on LMIC, which is why this research is so needed.*"

SME22 described the HII-MM's comprehensiveness as its' unique contributing factor, "*Well, there are models in the implementation science literature … I would say in general, they're much more high level, they're not nearly as complex and as detailed and as refined as this model … the main difference … is this [model] provides a very detailed, comprehensive assessment that allows you … to identify key areas … where success is happening and where challenges are happening … during the [implementation] process*." SME29 also pinpointed the HII-MM's comprehensiveness, commenting "*we use something similar when we evaluate new projects … [this model] covers parts that we don't usually cover, but having something structured as this will be useful to evaluate, let's say new innovations or new solutions tested with users*." Additionally, SME11 commented that the

HII-MM "*does provide a unique perspective – for the other models I looked at they didn't cover all of the domains, this model is comprehensive allowing you to critically assess [the system]*."

SME23 contemplated how the HII-MM reflects reality, "*I find it very useful actually, all the components that you've been mentioning, I think it reflects … reality … I've seen different frameworks; they only focus on the innovation itself … or it measures the stakeholders … So this is the first time I see something that collects a lot of multi-dimensions*."

Considering the HII-MM's specificity to the LMIC context, SME33 remarked, "*what this model provides … a unique way of asking or integrating questions that are LMIC specific because … some questions that might be in other frameworks may not be, speaking directly, to LMIC. And, the fact that you … can make this a very much a … context, specific adaptable tool, then it becomes even more relevant, even in high-income countries*." SME30 described the contextual factors which cater to the LMIC context as the HII-MM's unique contribution "*this definitely kind of provides a different perspective … [it] puts a lot of emphasis on all the contextual factors, which are very important, especially in low- middle-income countries*."

In addition to the LMIC-specific aspects of the HII-MM and its comprehensive nature, SME20 highlighted the HII-MM's ability to assess a health systems software and hardware, "*I think this adds something because it helps to consider that implementation happens at various different places and domains … that was something unique … I liked how you covered both … the software and the hardware.*" SME27 identified the inclusion of a maturation path as the HII-MM's unique contribution "*I would like to say that this is precisely what is lacking in most of the implementation models … inbuilt aspect of evolution.*"

9.2.4 Validation Interview Reflections

During the validation interviews, none of the SMEs contested the relevance, usefulness, usability or uniqueness questions posed. The only critique raised related to (i) the HII-MM's complexity potentially being a barrier to use, (ii) that not all of the implementation domains or health system levels are relevant to all innovations and (iii) that the HII-MM does not output a specific improvement process.

While it is necessary to ensure that the HII-MM is usable, there is a fine line between ensuring that the HII-MM is easy to use and has an adequate level of complexity that enables a holistic assessment of the complex, dynamic health innovation landscape. Simplifying the HII-MM falls outside this study's scope and could form part of future work. The concern that some domains or health system levels might not apply to all assessment scenarios is catered for in the operationalised HII-MM (refer to Chapter 7), as the user can choose to exclude health system levels or sub-domains perceived as irrelevant. The provision of an explicit improvement process falls outside this study's scope; however, the HII-MM maturation paths, an inherent feature of maturity models, enable the user to determine what should be improved and subsequently develop an improvement process. Where applicable, solutions to the three concerns, which fall outside of the current study's scope, are discussed in the opportunities for future work in Chapter 10, Section 10.4.

The SMEs concurred that the HII-MM is relevant to different LMICs and health innovation, highlighting its adaptability as important to ensuring its relevance. When discussing the HII-MMs relevance, SMEs frequently discussed the importance of the culture, which is often neglected when

assessing implementation processes. The SMEs deemed the HII-MM useful, with some expressing that they would like to use the HII-MM in their work. The visual aspects of the HII-MM, particularly the results sections, were highlighted as useful, along with the HII-MMs use of a system thinking perspective enlightening the user. Generally, the SMEs agreed that the HII-MM is usable and understandable, but that usability might differ between people with different skill sets. When asked to reflect on the HII-MM's uniqueness, the SMEs agreed that its features make it unique. SMEs had not come across a model that (i) focuses on LMICs, (ii) contains both hard and soft aspects of a health implementation landscape, (iii) includes a maturation path or (iv) is adaptable. It is concluded that the HII-MM is relevant, useful, usable, and unique. In the next section, the results from the practical validation of the HII-MM through two case studies are summarised.

9.3 VALIDATION CASE STUDIES

After the validation interviews, two case studies were carried out using the final HII-MM (as presented in Chapter 6 and operationalised in Chapter 7). The first case study was performed on the maternal health innovation MomConnect (refer to Section 9.3.2). The second case study was performed on the contact tracing innovation COVID Alert (refer to Section 9.3.3). The purpose of performing the case studies is to practically validate the relevance, usefulness, and usability of the HII-MM. The methodology followed to complete the case studies is described in the following section.

9.3.1 Validation Case Study Methodology

The case study protocol followed throughout this study is detailed in Chapter 2, Section 2.3.3.2. The protocol consists of four steps, namely: (i) define the case study, (ii) collect the data, (iii) analyse & interpret the data, and (iv) report on the results.

After the maturity assessments have been completed for all implementation domains, the results are used to conclude the barriers and facilitators in the assessed health system. The maturity assessment results can then be used to recommend potential improvement initiatives. In the following sections, the case study protocols are carried out for the MomConnect (Section 9.3.2) and COVID Alert (Section 9.3.3) case studies.

9.3.2 MomConnect

The first case study conducted using the final HII-MM is on implementing the evidence-based innovation, MomConnect, in South Africa. MomConnect is a South African, National Department of Health (NDOH) led mHealth innovation, which connects pregnant women and new mothers to services and health promotion messages (National Department of Health, 2022b). MomConnect was chosen as it has been lauded as one of the few successfully implemented mHealth innovations (Seebregts *et al.*, 2016); furthermore, there is a wealth of material available on MomConnect covering all of the HII-MM domains.

9.3.2.1 Defining the MomConnect Case Study

As described in the case study protocol (Chapter 2, Section 2.3.3.2), the first step is to define the chosen case study. In the following sub-sections, the various aspects of the general considerations user interface are described, (i) the MomConnect innovation is described, (ii) the specifics of the

implementation process are outlined and (iii) the health system into which the MomConnect innovation is implemented is described.

i) MomConnect General Considerations: Innovation

MomConnect is a mHealth innovation that provides pregnant women with stage-based health informational messages through a mobile phone (Heales and Green, 2016). The messages are sent to users using free SMS or the social media platform WhatsApp (Banning-Lover, 2020). The messages are available in all eleven official South African languages (Seebregts *et al.*, 2018). They have been developed to promote and improve pregnant women's and their babies health (Seebregts *et al.*, 2016). In addition to stage-based messaging, MomConnect includes interactive mechanisms that allow users to ask questions and provide feedback (Seebregts *et al.*, 2018).

By 2012, it was apparent that South Africa would not achieve Millennium Development Goals 4 and 5, for which targets to reduce child and maternal mortality had been set (Coleman J and Xiong K, 2017; Barron *et al.*, 2018). MomConnect was developed to reduce preventable maternal and neonatal deaths and improve maternal and neonatal health outcomes in South Africa (National Department of Health, 2022b; Praekelt, 2022b). To achieve this, MomConnect shares evidence-based health messaging to improve knowledge and increase health service use (Barron *et al.*, 2016; Coleman J and Xiong K, 2017; Pillay and Motsoaledi, 2018).

ii) MomConnect General Considerations: Implementation Process

The implementation stage of the innovation is sustainment. MomConnect has gone through a full South African national scale-up and has been integrated and sustained in public antenatal care (ANC) since its launch in August 2014 (Western Cape Government, 2014; Harrisberg and Pensulo, 2022). The stakeholders involved in the MomConnect implementation and sustainment process include (Western Cape Government, 2014; Pillay, 2015; Heales and Green, 2016; Seebregts *et al.*, 2016; Swartz *et al.*, 2021; Praekelt, 2022b):

i. Recipients of the innovation, pregnant women and mothers of newborns attending public health ANC services;
ii. Health workers who register people onto MomConnect, CHWs and ANC healthcare workers in public health facilities;
iii. Healthcare workers who operate the MomConnect helpdesk;
iv. Health facility managers, the district department of health personnel and the provincial department of health personnel who provide oversite;
v. Training partners, who train health workers how to use MomConnect;
vi. Technical partners: Praekelt, who developed the platform, Jembi health systems, who developed the interoperability components; and Health Information Systems Programme, South Africa (HISPSA), who managed the MomConnect data warehousing;
vii. Donors and funders, which include UNICEF, the United States President's Emergency Plan for AIDS Relief (PEPFAR), the US government, the Johnson and Johnson Foundation, ELMA Philanthropies, Discovery Foundation, and the South African National Department of Health;
viii. Implementation leads were the NDOH, championed by the minister for health and the Provincial Departments of Health. A task team was set up at the NDOH to manage the implementation of MomConnect; and
ix. Supporting the departments of health with the implementation, content development and strategising of MomConnect were over 30 partners, including (i) mobile network operators

(Telkom mobile, MTN, Cell C, and Vodacom) who provided discounts on the costs of SMS services, (ii) two South African universities who supported with the monitoring and evaluation, (iii) the Council for Scientific and Industrial Research, (iv) mHealth Alliance, (v) GSMA, (vi) CHAI, (vii) HealthEnabled, (viii) Soul City, (ix) International Coaching Federation, (x) Meraka Institute and (xi) Inner City Fund International.

MomConnect comprises five elements, (i) subscription service that is open to the public, providing limited messages and encouraging registration of the pregnancy at a public ANC clinic, (ii) health worker assisted registration where additional information is collected, including the expected due date and health facility; this allows tailored messages to be sent based on the pregnancy stage, (iii) sending evidence-based messages to registered users; the messages cover ANC, labour, diet, hypertension, infections, breastfeeding, newborn care and immunisation, (iv) rating of the health services received, and (v) submitting compliments and complaints (National Department of Health, 2022c).

The process followed in operationalising MomConnect is described in Figure 9.4. A pregnant woman goes into a public health clinic to attend their first ANC visit, and the nurse confirms the pregnancy and the estimated due date of delivery (Wolff-Piggott, Coleman and Rivett, 2018). The consenting woman is then registered on MomConnect using the MomConnect USSD application; registration takes place in one of three ways, either, (i) individual registration is performed where one person is registered at a time during their ANC, (ii) a group registration is performed, where a health worker guides a group of expectant mothers through the registration process, or (iii) batch registrations are performed where health workers keep a log of the information necessary to register a woman and then perform a batch registration when the clinic is not as busy (Measure Evaluation, 2016). As USSD is the lowest priority protocol, registration must be completed within approximately three minutes; otherwise, the user will have to restart the registration process (Wolff-Piggott, Coleman and Rivett, 2018).

The information needed to register a woman on MomConnect includes the estimated due date, the unique health facility code, which is validated, and the woman's mobile phone number (Seebregts *et al.*, 2016). A South African identity document (ID) number or a passport number are optional inputs; this was done because the time to capture these identification numbers could become a barrier due to the USSD time-outs (Seebregts *et al.*, 2018). Women can decide on their preferred language and whether they want to receive stage-based messages through SMS or WhatsApp. Once completed, the registered user will receive weekly stage-based messages; the pregnancy is also registered onto the national database (National Department of Health, 2022c). The messages are staged according to the inputted delivery date and provide information on healthy behaviour, what to expect during the different pregnancy stages and reminders to attend ANC visits (Banning-Lover, 2020). The user can opt-out at any time; if the user does not opt-out, the messages will stop once the child of the registered user turns one year old (National Department of Health, 2022c). In addition to the weekly messages, users are prompted to complete a service rating and can use the MomConnect helpdesk to submit questions, compliments or complaints (Barron *et al.*, 2018).

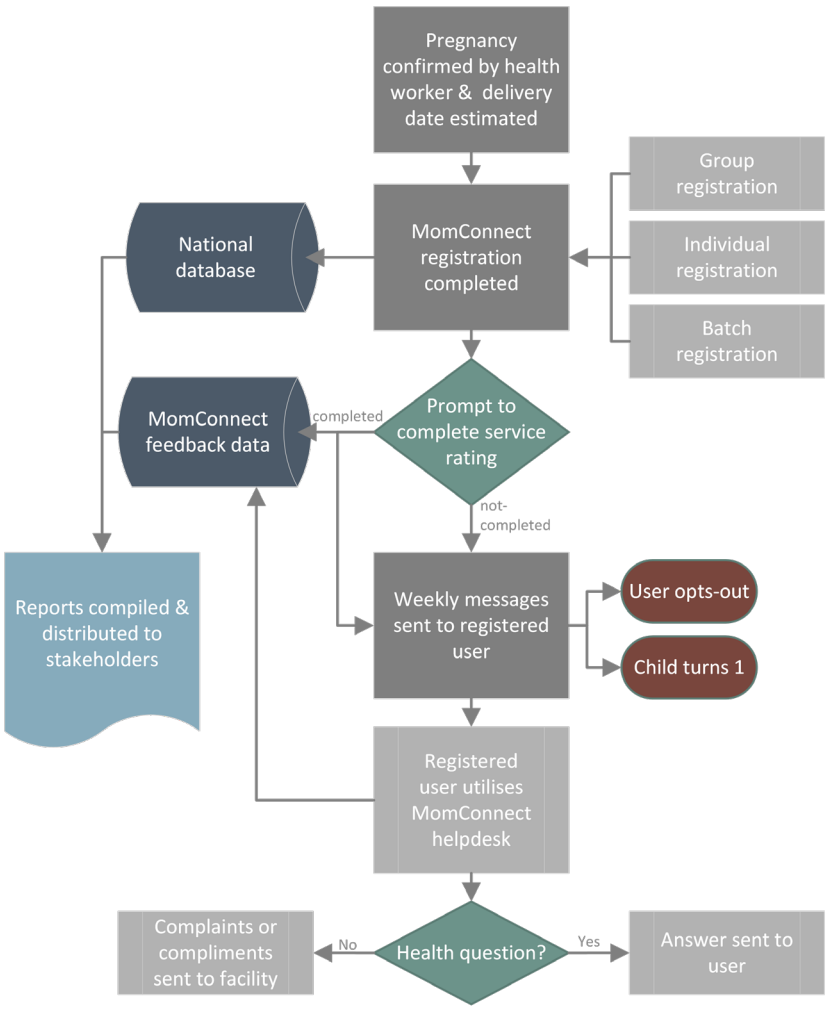

Figure 9.4: MomConnect process flow, developed from (Measure Evaluation, 2016; Seebregts *et al.*, 2016; Barron *et al.*, 2018; Wolff-Piggott, Coleman and Rivett, 2018; National Department of Health, 2022c)

iii) MomConnect General Considerations: Health System Levels

The macro-health system level assessed is the South African NDOH. South Africa is an upper-middle-income country (The World Bank, 2019). The South African health system consists of three tiers; the National Department of Health, the Provincial Departments of Health and the District Health System (National Department of Health, 2017a). The South African health system is decentralised; the District Health Systems are managed by the Provincial Departments of Health (National Department of Health, 2017a).

The meso-level considered for the case study is the Gauteng provincial department of health; Gauteng province is South Africa's smallest but most densely populated province (The Editors of Encyclopaedia Britannica, 2017). According to the 2019 antenatal survey, 66,9% of pregnant women in Gauteng sought ANC before 20 weeks of gestational age (Woldesenbet *et al.*, 2021). The 2019/20 maternal mortality in Gauteng was recorded at 102,9 per 100 000 live births, higher than the SDG of 70 and the neonatal death at 12,4 per 1 000 live births, also higher than the SDG of 12 (Massyn *et al.*, 2020). The micro-provider level covers the health workers in Gauteng public health facilities who register pregnant women onto MomConnect. The micro-community level assessed in the MomConnect case study consists of pregnant women attending ANC in Gauteng public health facilities.

9.3.2.2 MomConnect Data Collection

Snowball sampling was used to identify the data needed to complete the MomConnect case study. The April 2018 BMJ supplement "*Digital Health in South Africa: The case of MomConnect past, present, and future*", which consists of 11 articles, was used as a starting point for the snowball sampling approach. Over 30 additional online data sources were identified for inclusion in the case study. The sources include a mix of academic and grey literature, including press releases, news articles, government, developer and funder websites, demographic data, survey results, field assessments, systematic reviews, interviews, comparative reviews, and field research. The information and data published on MomConnect cover all of the HII-MM domains; additionally, the available data uses different methodologies, ensuring that a wide range of data sources are used to complete the case study. There are no ethical concerns for the MomConnect case study; it is a desk-based case study with no stakeholder engagement.

9.3.2.3 MomConnect Case Study Results

Maturity levels are decided on by using the maturity assessment matrix. Once collected, the data are summarised and categorised according to the HII-MM domains, sub-domains, and health system levels. The categorised data are then analysed to establish the maturity score for each sub-domain and at each health system level. The maturity results for each domain are presented and described in the following sub-sections.

i) MomConnect: Innovation Domain Results

Data relevant to MomConnect's innovation sub-domains (i) design & functionality, (ii) supporting evidence, and (iii) ethics & equity were analysed to determine their respective maturity levels. The MomConnect case study results for the innovation domain are summarised in Figure 9.5.

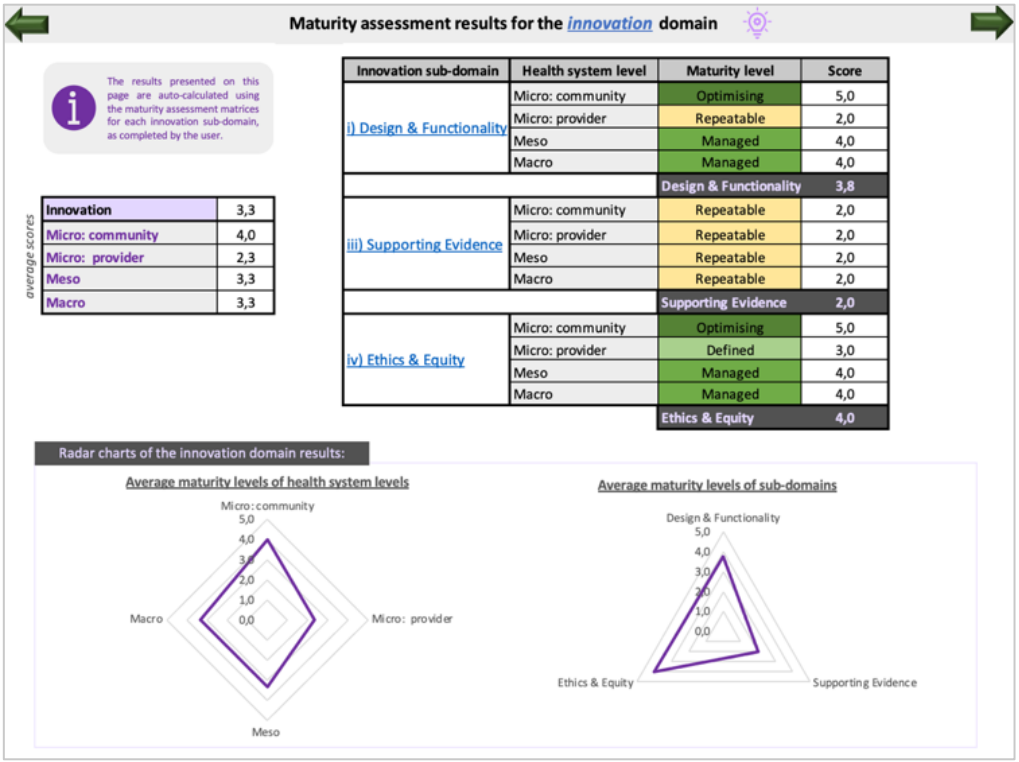

Figure 9.5: Innovation domain results page for the MomConnect case study

Figure 9.5 shows that the innovation domain's summary maturity score is at level 3,3, *defined*. The innovation sub-domain that achieved the lowest maturity score was supporting evidence at 2,0, and the health system level scoring the lowest was the health provider level at 2,3; these areas should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the innovation domain.

i.i) MomConnect: Innovation Maturity at Micro-Community Level

The average innovation maturity score for the micro-community level is level 4,0 *managed*. Table 9.2 summarises the elements supporting the identified micro-community maturity levels for each innovation sub-domain.

Table 9.2: MomConnect summary of the innovation maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Design & functionality	**5**	MomConnect is based on the community's needs for health education, and its functionality is interoperable with the community's socio-demographics. Additionally, the design of MomConnect is adaptable and has been adapted to meet the changing technological landscape. The combination of high literacy rates, the ability to choose a preferred language and mobile phone penetration among South African women make the MomConnect innovation interoperable with the community of pregnant women it targets.
Supporting evidence	**2**	The limited evidence existing to support the improved health outcomes resulting from exposure to MomConnect messages could impact sustainability, particularly when motivating for funding.
Ethics & Equity	**5**	MomConnect has been designed ethically and equitably. The design ensures comprehensive coverage and is usable in low-resource settings; furthermore, appropriate data security measures are in place.

The maturity of MomConnect's design & functionality at the micro-community level was identified as level 5. MomConnect was designed in collaboration with local experts to ensure it was appropriate to the South African context (Seebregts *et al.*, 2016); the MomConnect messages were tested prior to the national roll-out to ensure that they are based on the community's needs (Skinner *et al.*, 2018). MomConnect sends registered women tailored health education messages twice a week, covering ANC and postpartum messaging (Livingston Mehl *et al.*, 2018). MomConnect addresses pregnant women's health education and health promotion wants and needs (Myer and Harrison, 2003; Hoque *et al.*, 2006; Noncungu and Chipps, 2020).

Pregnant women formally register for MomConnect during their first ANC visit to a public health facility (Barron *et al.*, 2018). Formal registration occurs at a health facility where the pregnancy is confirmed; the delivery date is estimated to ensure the stage-based MomConnect messages are sent at the correct gestational stages. (Barron *et al.*, 2018). In the 2019 ANC survey, South African ANC initiation in public health facilities before 20 weeks was estimated at 70,1% (Woldesenbet *et al.*, 2021), highlighting that MomConnect registration at the first ANC visit is a viable option. Therefore, the registration requirements are interoperable with most of the target population.

MomConnect makes use of (i) unstructured supplementary service data (USSD), a session-based information-sharing protocol, and (ii) SMS, a protocol that enables sending, receiving and storing messages of up to 160 characters. USSD is used to register people on MomConnect, and SMS is

used to share evidence-based messages with and obtain feedback from registered MomConnect users (Seebregts *et al.*, 2016, 2018). MomConnect's technology has been designed to be interoperable with basic mobile phones, which ensures it is accessible to anyone in South Africa who has access to a mobile phone (Peter *et al.*, 2018; Maliwichi, Chigona and Sowon, 2021). In 2017, three years after its launch, the option of receiving MomConnect messages via WhatsApp, a social media messaging platform, was introduced (Shapshak, 2017). However, of those with WhatsApp who registered for MomConnect, only 20% opted for WhatsApp as the preferred channel to receive the MomConnect messages, citing WhatsApp data costs as a deterrent (Digital Impact Alliance, 2018).

South Africa has high coverage of mobile phones, among females and males, at over 80% (Peter, Barron and Pillay, 2016; Barron *et al.*, 2018; Livingston Mehl *et al.*, 2018; Rowntree and Shanahan, 2020). Furthermore, South Africa has high rates of adult literacy. In 2019, World Bank reported adult female literacy rates to be at 95% (The World Bank, 2021b). South Africa has eleven official languages (Republic of South Africa, 1996), which MomConnect caters for by allowing the user to choose which language to receive the MomConnect messages in (National Department of Health, 2022b). Some users raised challenges with the Xhosa dialect being too traditional and difficult to understand, changing their language preference to English (Skinner *et al.*, 2018; Ezezika, Varatharajan and Racine, 2020). Xhosa dialects differ in different South African regions (Paxton, 2009), contributing to a Xhosa person's understanding of the MomConnect messages (Skinner *et al.*, 2018; Ezezika, Varatharajan and Racine, 2020).

The maturity of MomConnect's supporting evidence at the micro-community level was identified as level 2. MomConnect's messages cover health behaviours linked to enhanced maternal and neonatal health outcomes; messages cover evidence-based interventions such as handwashing, nutrition, illness, breastfeeding, ANC uptake, HIV and immunisation (Barron *et al.*, 2018; Peter, 2018). There is evidence that providing health education improves pregnancy outcomes, and mHealth innovations can improve access to health education (Seebregts *et al.*, 2016; Ramnund *et al.*, 2021). While some research has shown that exposure to MomConnect messages improves breastfeeding practices (Trafford *et al.*, 2020), there is not a strong or established evidence base showing the links between exposure to MomConnect messages and changes in health outcomes (Swartz *et al.*, 2021).

The maturity of MomConnect's ethics & equity at the micro-community level was identified as level 5. Registration on MomConnect is voluntary, and the data collected are stored on secure NDOH servers (Barron *et al.*, 2018; Seebregts *et al.*, 2018). Users raise some privacy concerns. MomConnect messages could be read by anyone with access to the mobile phone, with HIV-positive users particularly concerned that the MomConnect messages might disclose their HIV status to someone who might look at their mobile phone (Skinner *et al.*, 2018). MomConnect is equitable as it does not exclude people based on their socioeconomic status. It is free for pregnant women to use, the technology required to use MomConnect is available on all mobile phones, the telecommunication infrastructure needed for SMS and USSD is more widely available compared to internet connectivity which has low coverage in rural areas, and registration on MomConnect can be done on any mobile phone accessible to the pregnant woman, i.e., registration is not contingent on a community member owning a phone (Seebregts *et al.*, 2016, 2018; Livingston Mehl *et al.*, 2018; Maliwichi, Chigona and Sowon, 2021). MomConnect does not exclude documented immigrants, as there is a provision to include a passport number in place of an ID number during registration. It also

does not exclude undocumented immigrants; if no ID number or passport number is available, the date of birth can be used to register pregnant women (Sebidi, 2018).

i.ii) MomConnect: Innovation Maturity at Micro-Provider Level

The average innovation maturity score for the micro-provider level is level 2,3 repeatable. Table 9.3 summarises the elements supporting the identified micro-provider maturity levels for each innovation sub-domain.

Table 9.3: MomConnect summary of the innovation maturity at micro-provider level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Design & functionality	**2**	There are gaps in MomConnect's interoperability with health providers' immediate needs, and its functionality is not fully interoperable with the existing processes in which it is expected to operate.
Supporting evidence	**2**	The evidence supporting MomConnect's benefits to health providers is indirect, and they are not well-defined or well-established, which could, in-turn, impact longevity.
Ethics & Equity	**3**	MomConnect has been designed ethically and equitably. However, there are some practices in health facilities that might lead to privacy breaches, specifically when batch registrations are performed (women's details are recorded on paper and registered by a health worker at a later point using their device or a facility device).

The maturity of MomConnect's design & functionality sub-domain at the micro-provider level was identified as level 2. USSD functionality, available on all cellular phones across the country, is used to formally register pregnant women for MomConnect in health facilities. USSD is easy to operate and is commonly used in South Africa to load airtime; thus, it is interoperable with the providers who register community members or guide the registration process (Seebregts *et al.*, 2016; Barron *et al.*, 2018). The number dialled to activate the registration process is the same for all mobile operating networks, which increases the ease of use for the providers who assist with the registration processes (Seebregts *et al.*, 2016). The technology used in MomConnect is interoperable with the providers; however, the positioning of the registration in facilities is not fully interoperable with ANC processes in facilities that tend to be in high demand. This aspect is discussed further in the resources domain. The registration process is in English, which was not identified as a barrier to the providers; the language of instruction for most nurses in South Africa is English (Ndawo, 2019).

Neither the community members nor the providers were directly involved with the design of MomConnect; however, lessons from a formative pilot project, Mobile Alliance for Maternal Action, were used to develop MomConnect and ensure it was adapted to the South African context (Haseki, Yoo and Srinivasan, 2019a; Ezezika, Varatharajan and Racine, 2020). MomConnect does not directly address health providers' needs for information, reduced workloads or increased staffing (Willis-Shattuck *et al.*, 2008).

The maturity of MomConnect's supporting evidence at the micro-provider level was identified as level 2. Similar to the community level, there is some evidence of the benefits of health education improving maternal and neonatal health outcomes, which would, in turn, benefit health providers by reducing workloads and complicated pregnancy cases. However, the evidence is not well-defined or well-established.

The maturity of MomConnect's ethics & equity at the micro-provider level was identified as level 3. The technology is equitable as it is available in urban and rural settings. Registration is supposed to be done by the nurse attending to women at their first ANC visit using the women's phone (Swartz *et al.*, 2021). However, this is rarely how the registration process is completed due to understaffed facilities attending to high volumes of women; instead, batch registrations are utilised to minimise disruptions to service provision (Swartz *et al.*, 2021). As batch registrations are not standard, there are no operating procedures, guidelines or training available to support the alternative registration method; this has implications for the data security, accuracy and the recording of consent (Measure Evaluation, 2016; Swartz *et al.*, 2021).

i.iii) MomConnect: Innovation Maturity at Meso-Level

The average innovation maturity score for the meso-level is level 3,3 *defined*. Table 9.4 summarises the elements supporting the identified meso- maturity levels for each innovation sub-domain.

Table 9.4: MomConnect summary of the innovation maturity at meso-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Design & functionality	**4**	MomConnect is interoperable with the systems at the meso-level and with the Gauteng Department of Health's mission and is thus needs-based.
Supporting evidence	**2**	The evidence supporting MomConnect's benefits to Gauteng's population health outcomes is not well-defined or well-established.
Ethics & Equity	**4**	MomConnect has been designed ethically and equitably, with the data collected stored on secure NDOH servers, which are continuously monitored for data safety.

The maturity of MomConnect's design & functionality sub-domain at the meso-level was identified as level 4. The Gauteng Department of Health's mission is to "*create an effective public healthcare system by ensuring we have the right people, skills, system and equipment to provide the care our patients need to live healthy and quality lives*" (Gauteng Provincial Government, 2022). MomConnect contributes to this mission by providing ANC patients with evidence-based information to improve their and their newborn's health. MomConnect is interoperable with the existing meso-level systems, namely the District Health Information System (DHIS2). MomConnect uses the demographic registry and clinical repository module on DHIS2, which enables provincial officials to monitor performance using a familiar platform (Seebregts *et al.*, 2016).

The maturity of MomConnect's supporting evidence at the meso-level was identified as level 2. As discussed in the micro-levels, while there is evidence that information-sharing mHealth interventions improve health-related behaviours (Lefevre *et al.*, 2018), the efficacy of these interventions is lacking (Coleman J and Xiong K, 2017).

The maturity of MomConnect's ethics & equity at the meso-level was identified as level 4. MomConnect has been designed ethically and equitably, with the data collected stored on secure NDOH servers continuously monitored for data safety. The ethical implications of storing patient-level data are covered by the national-level data systems and protocols that provinces then use; these will be discussed in detail in the following sub-section.

i.iv) MomConnect: Innovation Maturity at Macro-level

The average innovation maturity score for the meso-level is level 3,3 *defined*. Table 9.5 summarises the elements supporting the identified macro-maturity levels for each innovation sub-domain.

Table 9.5: MomConnect summary of the innovation maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Design & functionality	**4**	MomConnect is based on the South African NDOH's needs to improve maternal and neonatal health outcomes; it is also interoperable with the macro-level technical infrastructure.
Supporting evidence	**2**	There is insufficient evidence specific to MomConnect showing the impact behavioural change interventions have on South Africa's maternal and newborn health outcomes.
Ethics & Equity	**4**	MomConnect has been designed ethically and equitably, with the data collected stored on secure NDOH servers, which are continuously monitored for data safety.

The maturity of MomConnect's design & functionality sub-domain at the macro-level was identified as level 4. MomConnect was designed to be interoperable with the existing NDOH technical infrastructure and to allow for adaptation over time (Seebregts *et al.*, 2016; Peter, 2018; Peter *et al.*, 2018). The technical infrastructure connects demographic and clinical databases stored on DHIS2 (South Africa's official health information system) with the user application, i.e. the MomConnect application, using an interoperability layer (Seebregts *et al.*, 2016). MomConnect's infrastructure was developed with a simple backend to ensure that the administration and maintenance of MomConnect are user-friendly (Seebregts *et al.*, 2016). Furthermore, MomConnect is based on the NDOH need to reduce preventable maternal and neonatal deaths, improve maternal and neonatal health outcomes and achieve universal health coverage in South Africa (Barron *et al.*, 2018; National Department of Health, 2022b; Praekelt, 2022b).

The maturity of MomConnect's supporting evidence at the macro-level was identified as level 2. Insufficient evidence supporting MomConnect's benefits and efficacy has been identified as a constraint to obtaining sustainable funding sources (Peter *et al.*, 2018; Ezezika, Varatharajan and Racine, 2020). Establishing an evidence base prior to scale-up would allow for easier comparisons verifying the effectiveness and justifying continued investment (Peter *et al.*, 2018; Ezezika, Varatharajan and Racine, 2020).

The maturity of MomConnect's ethics & equity at the macro-level was identified as level 4. The integrity and security of MomConnect's system were key considerations during its design (Seebregts *et al.*, 2018); data collected through MomConnect are stored on servers secured and controlled by the NDOH (Barron *et al.*, 2018). The servers housing the data are protected through a firewall (Seebregts *et al.*, 2018) and data are encrypted whenever it is transmitted between components (Seebregts *et al.*, 2016). The inclusion of WhatsApp as a channel to receive MomConnect messages is a more secure way of sending messages, as WhatsApp is end-to-end encrypted (Shapshak, 2017; Banning-Lover, 2020).

ii) MomConnect: Resources Domain Results

Data relevant to MomConnect's resources sub-domains (i) infrastructure, services & physical resources, (ii) human resources, and (iii) financial resources were analysed to determine their

respective maturity levels. The MomConnect case study results for the resources domain are summarised in Figure 9.6.

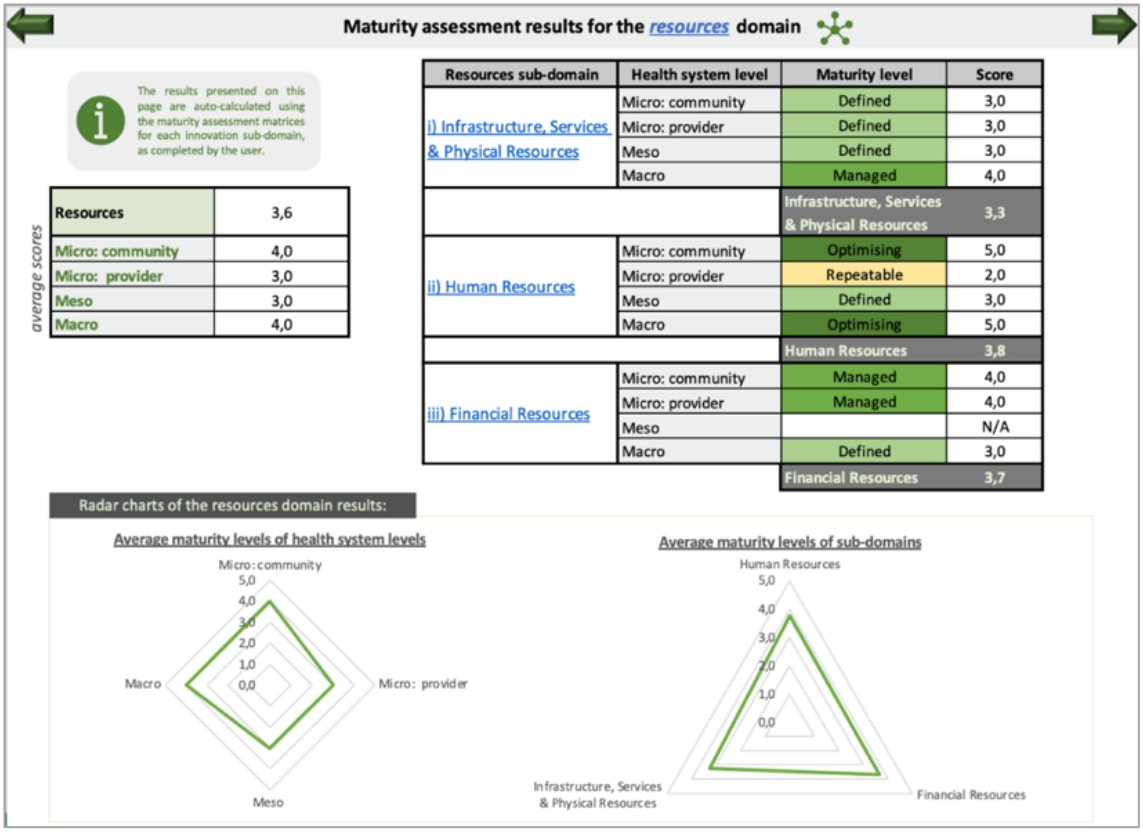

Figure 9.6: Resources domain results for the MomConnect case study

Figure 9.6 shows that the summary maturity score for the resources domain is at level 3,6 *defined*. The resources sub-domain that achieved the lowest maturity score was infrastructure, services & physical resources at 3,3, and the health system level scoring the lowest was the micro-provider and meso-level, both at 3,0; these maturity levels are within the defined level. The one area that should be targeted in developing improvement interventions is the micro-provider human resources sub-domain. The following sub-sections present details of the data collected for the resources domain.

ii.i) MomConnect: Resources Maturity at Micro-Community Level

The average resources maturity score for the micro-community level is level 3,6 *defined*. Table 9.6 summarises the elements supporting the identified micro-community maturity levels for each of the resources sub-domain.

Table 9.6: MomConnect summary of the resources maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Infrastructure, services & physical resources	3	Infrastructure, health services, and physical resources enable the use of MomConnect by the community. The telecommunications infrastructure in South Africa covers a high proportion of the population. The services that enable the use of MomConnect by South Africans are the availability of ANC services in public health facilities.
Human resources	5	There are community members present who champion the innovation, and time is not identified as a barrier to community members using the innovation (this becomes a barrier at the health provider level).
Financial resources	4	MomConnect has been designed for the user to carry no operating costs, except for data costs, when a user opts to use WhatsApp instead of SMSs. Costs associated with reaching health facilities were not identified as a barrier.

The maturity of MomConnect's infrastructure, services & physical resources sub-domain at the micro-community level was identified as level 3. As described in Section 9.3.2.1, the MomConnect registration process uses USSD codes, and the same toll-free codes are available on the major South African mobile network operators (Seebregts *et al.*, 2016). USSD is easy to operate and commonly used in South Africa to load airtime; however, time-outs or network failures are often experienced when using USSD, increasing the registration time (Seebregts *et al.*, 2016; Barron *et al.*, 2018). The telecommunication infrastructure and services available to the community support MomConnect; there is 99,9% mobile network coverage[18] in South Africa (The Global Economy, 2016).

There is a high likelihood that the mobile phone would be available to pregnant women wanting to enrol on MomConnect. As discussed in the innovation domain, South Africa has mobile phone penetration of over 80% (Peter, Barron and Pillay, 2016; Barron *et al.*, 2018; Livingston Mehl *et al.*, 2018; Rowntree and Shanahan, 2020). If a woman does not own a mobile phone, she can opt for the messages to be sent to another phone she can access (Skinner *et al.*, 2018). It is estimated that 15,6% of the South African population does not have access to electricity (The World Bank, 2020). This poses a barrier for some women who live in informal settlements without electricity and might not own a mobile phone because of difficulties charging (Wolff-Piggott, Coleman and Rivett, 2018; Mogoba *et al.*, 2019). Other women would travel to the health facility without their phones due to safety concerns when queuing in the dark (Wolff-Piggott, Coleman and Rivett, 2018).

MomConnect's human resources maturity at the micro-community level was identified as level 5. There were community members, MomConnect users, who championed MomConnect among their friends and other community members (University of Witwatersrand, 2016). Time to complete the MomConnect registration process was not identified as a barrier for the community members; this was, however, a challenge at the health provider level.

The maturity of MomConnect's financial resources at the micro-community level was identified as level 4. ANC is offered free of charge in public health facilities in South Africa (Solarin and Black, 2013). There is high coverage of women attending at least one ANC visit in Gauteng during their pregnancy at 90,2% (Massyn *et al.*, 2020), highlighting that there would be suitable access to the

[18] The proportion of people who are in the range of mobile phone signal (The Global Economy, 2016)

services that enable and complement MomConnect, and transportation costs are not a barrier. Community members do not have to pay to register for MomConnect, and the MomConnect SMSs do not cost the user (Livingston Mehl *et al.*, 2018); however, if a user opts to receive the messages through WhatsApp, the user will pay the WhatsApp data costs. There has not been a high uptake of users requesting WhatsApp as the channel to receive the MomConnect messages, with most users preferring to receive the messages via SMS (Digital Impact Alliance, 2018).

ii.ii) MomConnect: Resources Maturity at Micro-Provider Level

The average resources maturity score for the micro-provider level is level 3,0 ***defined***. Table 9.7 summarises the elements supporting the identified micro-provider maturity levels for each of the resources sub-domain.

Table 9.7: MomConnect summary of the resources maturity at micro-provider level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Infrastructure, services & physical resources	**3**	Infrastructure, services & physical resources enable the use of MomConnect by the providers. Telecommunications infrastructure covers a large proportion of health facilities. Challenges with network quality and USSD time-outs were barriers to successful registration.
Human resources	**2**	There is a high turnover of human resources working in ANC, staff shortages and considerable time pressures experienced by these human resources, to which MomConnect adds.
Financial resources	**4**	There are no financial implications for the health workers providing the services; the innovation is integrated into the day-to-day ANC operations.

The maturity of MomConnect's infrastructure, services & physical resources sub-domain at the micro-provider level was identified as level 3. The telecommunications infrastructure in South Africa covers a high proportion of the population at 99,9% mobile network coverage in South Africa (The Global Economy, 2016), which includes health facilities. However, the health providers highlighted challenges include network and time-outs, which were identified as the main barriers to registering community members onto MomConnect impeding program coverage (Xiong and Iskarpatyoti, 2017; Barron *et al.*, 2018; Swartz *et al.*, 2021). When the MomConnect registration process is unsuccessful, health providers do not always re-attempt the registration process (Xiong and Iskarpatyoti, 2017; Swartz *et al.*, 2021). There were some scenarios where the health worker would take the details of unsuccessfully registered community members to register them later (Skinner *et al.*, 2018). The network and time-out challenges cost the health provider time and increase patient waiting time, leading to lost registrations and unnecessary network charges (Barron *et al.*, 2018; Skinner *et al.*, 2018).

MomConnect's human resources maturity at the micro-provider level was identified as level 2. The registration process is a time burden on the health providers as there is a high demand for ANC services and the health facilities tend to have insufficient or shortages of health workers, particularly professional nurses who were expected to register women onto MomConnect (Heales and Green, 2016; Measure Evaluation, 2016; Wolff-Piggott, Coleman and Rivett, 2018; Swartz *et al.*, 2021). There is a high turnover of staff in the facilities (Measure Evaluation, 2016); this influences implementation as there is a continuous need for orientation on MomConnect and has implications on the presence of implementation individuals – champions, coordinators, etc. These challenges have resulted in either general ANC services being prioritised over MomConnect registrations, batch

registrations being performed, task sharing or task-shifting arrangements being developed where support staff would manage the registration process (Wolff-Piggott, Coleman and Rivett, 2018; Swartz *et al.*, 2021).

There were also staffing challenges with the help desk staff, the health workers who answered questions and responded to compliments and complaints posed by MomConnect users (Barron *et al.*, 2018). There were human resource gaps among the help desk staff, particularly around nurses able to respond in Zulu and Xhosa (Xiong, Kamunyori and Sebidi, 2018).

The maturity of MomConnect's financial resources at the micro-provider level was identified as level 4. There are no financial implications for the health workers registering women onto MomConnect as the intervention is integrated into the day-to-day ANC operations. No financial incentives were provided to the health workers to promote MomConnect, and no additional equipment needed to be bought at the provider level to enable the implementation of MomConnect.

ii.iii) MomConnect: Resources Maturity at Meso-Level

The average resources maturity score for the meso-level is level 3,0 *defined*. Table 9.8 summarises the elements supporting the identified meso-maturity levels for each resources sub-domain.

Table 9.8: MomConnect summary of the resources maturity at meso-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Infrastructure, services & physical resources	**3**	Infrastructure, services & physical resources at the meso-level enable the functionality of MomConnect; this includes the provision of public health services and the data systems present.
Human resources	**3**	There are MomConnect champions present at the meso-level
Financial resources	**N/A**	The maturity of MomConnect's financial resources at the meso-level was deemed not applicable because there are no financial implications at the provincial level; the financing and identification of long-term funding sources for MomConnect are made at the macro- (NDOH) level.

The maturity of MomConnect's infrastructure, services & physical resources sub-domain at the meso-level was identified as level 3. Infrastructure available and present at the meso-level supports MomConnect's functionality to store the MomConnect data effectively and monitor the registrations completed per health facility, namely, the DHIS2 (Seebregts *et al.*, 2018). With the municipal authorities, the Gauteng department of health provides public health services that enable MomConnect (Wolff-Piggott, Coleman and Rivett, 2018).

MomConnect's human resources maturity at the meso-level was identified as level 3. Provincial personnel act as champions of MomConnect, coordinating and ensuring integration into maternal and child activities (Peter *et al.*, 2018); furthermore, there are MomConnect district-level champions identified (Barron *et al.*, 2018).

ii.iv) MomConnect: Resources Maturity at Macro-level

The average resources maturity score for the macro-level is level 4,0 *managed*. Table 9.9 summarises the elements supporting the identified macro-maturity levels for each resources sub-domain.

Table 9.9: MomConnect summary of the resources maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Infrastructure, services & physical resources	4	Infrastructure, services & physical resources at the macro-level enable the functionality of MomConnect. The existing technical infrastructure, systems and maintainability of the systems were all facilitators.
Human resources	5	Multiple implementation individuals were present at the macro-level, including a coordinator, networker and multiple champions.
Financial resources	3	Donors funded the initial costs of MomConnect, with the NDOH taking over day-to-day funding in 2018. The financial sustainability of MomConnect is a challenge due to insufficient evidence supporting the innovation, making it challenging to develop an investment case for sustained government funding.

The maturity of MomConnect's infrastructure, services & physical resources sub-domain at the macro-level was identified as level 4. To develop MomConnect, existing technical infrastructure (open enterprise patient index, open medical record system and DHIS2) was integrated using the NDOH standards-based framework to develop an interoperability layer (Seebregts *et al.*, 2016; Livingston Mehl *et al.*, 2018). Using established infrastructure saved development costs and improved the reliability of the MomConnect infrastructure. The maintenance of these components has been designed to be user-friendly and can be easily maintained and updated without disrupting the operations of MomConnect (Seebregts *et al.*, 2018). The technical infrastructure that enables the sending and receiving of the MomConnect messages is managed externally by the mobile network operators as part of their core business processes; this includes the maintenance of the infrastructure (Wolff-Piggott, Coleman and Rivett, 2018).

The maturity of MomConnect's human resources at the macro-level was identified as level 5. There was a presence of multiple different implementation individuals at the macro-level, including a coordinator (technical advisor), networker (technical advisor, deputy director general and minister of health) and multiple champions (deputy director general and the minister of health). Existing human resources at the macro-level were leveraged to enable the implementation of MomConnect. MomConnect is the responsibility of the maternal and child health deputy director general at the NDOH, who is supported by a technical advisor who runs the MomConnect task team (Peter *et al.*, 2018; Swartz *et al.*, 2021). The task team comprises academic partners, donors, technological partners, and individuals from NDOH maternal and neonatal programmes (Swartz *et al.*, 2021).

During inception and roll-out, the minister of health championed MomConnect, launching it in each of the nine provinces, closely monitoring registration trends and acknowledging the achievement of milestones with events (Seebregts *et al.*, 2016; Peter *et al.*, 2018). Even with human resource turnover at the macro-level, the turnover rate was not rapid, which allowed MomConnect to become ingrained in NDOH. The minister of health who championed MomConnect served for six years, from 2014 to 2019 (South African Government, 2022).

The maturity of MomConnect's financial resources at the macro-level was identified as level 3. A significant upfront investment was received to implement MomConnect. The investment was from donors with a commitment from the department of health to fund MomConnect's core elements, e.g., data storage, messaging, USSD, help desk, technical platforms, training, and revision of the message content (Peter, 2018; Peter *et al.*, 2018; Seebregts *et al.*, 2018). The NDOH took over the financing of the daily upkeep of MomConnect in 2018 (Banning-Lover, 2020), there is still a reliance on donors to fund improvements ensuring that MomConnect keeps up with the changing technological landscape or user needs (Peter, 2018; Banning-Lover, 2020).

The open-source technical infrastructure has reduced the need to pay licensing costs (Seebregts *et al.*, 2016). The SMS costs account for approximately three-quarters of the MomConnect running costs; this is even with the four largest mobile network operators – Cell C, MTN, Telkom and Vodacom – subsidising the costs of the SMSs by up to 50% (Seebregts *et al.*, 2016; Barron *et al.*, 2018; Peter *et al.*, 2018). The economies of scale of SMSs are limited, making it costly to scale using SMSs (Peter *et al.*, 2018; Seebregts *et al.*, 2018). There are also financial implications for each repeat or failed USSD registration session, as these are reverse billed (Barron *et al.*, 2018; Wolff-Piggott, Coleman and Rivett, 2018). The mobile network operators practice re-using inactive pre-paid phone numbers after about three months which can incur unnecessary costs (Seebregts *et al.*, 2018).

The financial sustainability of MomConnect has been a challenge (Sebidi, 2018). MomConnect has high coverage, reaching over 60% of pregnant women (Livingston Mehl *et al.*, 2018), and its resulting annual cost is not high compared to its usage and the total public health budget (Barron *et al.*, 2018). However, because it is difficult to show the advantages of MomConnect over other interventions, it could represent an opportunity cost during economic restrictions (Barron *et al.*, 2018; Peter, 2018). As discussed in the innovation domain, there is insufficient evidence supporting MomConnect's cost-effectiveness and effects on health outcomes. This has made it challenging to develop an investment case for sustained government funding (Peter, 2018; Swartz *et al.*, 2021).

iii) MomConnect: Institutions Domain Results

Data relevant to MomConnect's institutions sub-domains (i) laws & regulations, (ii) policies, (iii) standards & guidelines, and (iv) institutions & priorities were analysed to determine their respective maturity levels. The MomConnect case study results for the institutions domain are summarised in Figure 9.7.

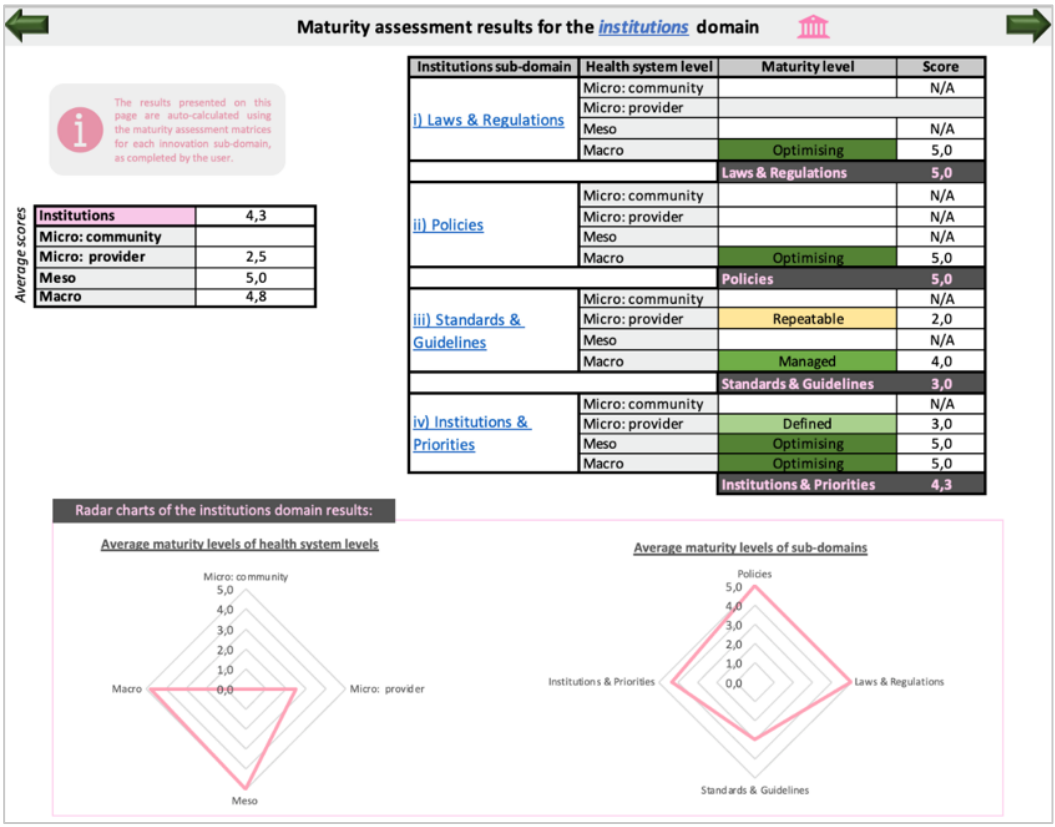

Figure 9.7: Institutions domain results for the MomConnect case study

Figure 9.7 shows that the summary maturity score for the institution's domain is at level 4,3 *managed*. The institutions sub-domain that achieved the lowest maturity score was standards & guidelines at 3,0, defined, and the health system level scoring the lowest was the micro-provider level at 2,5 repeatable; both of these areas should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the institutions domain. The micro-community level is not presented for this domain, as no institutions, policies, laws & regulations, or standards & guidelines are present at this level.

iii.i) MomConnect: Institutions Maturity at Micro-Provider Level

The average institutions maturity score for the micro-provider level is level 2,5 *repeatable*. Table 9.10 summarises the elements supporting the identified micro-provider maturity levels for each institutions sub-domain.

Table 9.10: MomConnect summary of the institutions maturity at micro-provider level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Laws & regulations	**N/A**	Laws & regulations do not apply to the micro-provider level.
Policies	**N/A**	Policies do not apply to the micro-provider level.
Standards & guidelines	**2**	Standards & guidelines equipping health providers to use MomConnect were generally lacking.
Institutions & priorities	**3**	MomConnect supports the priorities of health facilities. However, it is seen as a peripheral activity to health service provision.

The maturity of standards & guidelines at the micro-provider level was identified as level 2. Some existing material supporting health facilities included workflows and training material (Wolff-Piggott, Coleman and Rivett, 2018). However, there were no standardised methods for registration (Measure Evaluation, 2016), no clear monitoring plans (Peter *et al.*, 2018), reporting protocols, supervision or management structures supporting the implementation of MomConnect (Measure Evaluation, 2016).

The maturity of institutions & priorities at the micro-provider level was identified as level 3. The institutions at the micro-provider level include the health facilities, and their priorities are to efficiently and effectively provide health services (Gauteng Department of Health, 2020). The health facility managers' priorities are to ensure safe and effective health services and manage resources (National Department of Health, 2011). While MomConnect supports the priorities of health facilities, it is a peripheral activity; facility managers are more concerned with the provision of satisfactory healthcare and addressing critical resource shortages (Wolff-Piggott, Coleman and Rivett, 2018)

iii.ii) MomConnect: Institutions Maturity at Meso-Level

The average institutions maturity score for the meso-level is level 5,0 optimising. Table 9.11 summarises the elements supporting the identified meso-maturity levels for each institutions sub-domain.

Table 9.11: MomConnect summary of the institutions maturity at meso-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Laws & regulations	**N/A**	Laws & regulations were not assessed for the meso-level as there are not specific to the meso-level MomConnect context.
Policies	**N/A**	Policies were not assessed for the meso-level as there are not specific to the meso-level MomConnect context.
Standards & guidelines	**N/A**	Standards & guidelines were not assessed for the meso-level as there are not specific to the meso-level MomConnect context.
Institutions & priorities	**5**	The Gauteng department of health's priorities correlates with MomConnect's aims and objectives, indicating that there would be long-term institutional support at the meso-level.

The maturity of the institutions and institutional priorities at the meso-level was identified as level 5. The institutions present at the meso-level are the Gauteng Department of health, and their institutional priorities are improved health and well-being for all, which MomConnect aims to achieve for expectant mothers (Gauteng Provincial Government, 2022).

iii.iii) MomConnect: Institutions Maturity at Macro-level

The average institutions maturity score for the macro-level is level 4,8 *managed*. Table 9.12 summarises of the elements supporting the identified macro-maturity levels for each institutions sub-domain.

Table 9.12: MomConnect summary of the institutions maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Laws & regulations	5	South Africa's laws & regulations create an enabling environment for the design and implementation of MomConnect.
Policies	5	South Africa has a very supportive policy landscape that enables the design, implementation and scaling of mHealth innovations.
Standards & guidelines	4	Standards & guidelines exist to support some of the MomConnect processes. However, there are gaps surrounding some of the more granular processes, e.g., removing users and different registration methods.
Institutions & priorities	5	MomConnect is closely aligned with the NDOH priorities and the international health priorities outlined by the WHO and UN.

The maturity of laws & regulations at the macro-level was identified as level 5. The regulation that supports the design and implementation of MomConnect is the National Health Act 61 of 2003. The regulation that restricts the design & functionality of MomConnect is the Protection of Personal Information Act 4 of 2013 (POPIA). POPIA regulates how the patient information MomConnect utilises is collected and stored (Seebregts *et al.*, 2016), ensuring that the ethical aspects of managing identifiable information are adhered to (refer to Section 9.3.2.3 i)). POPIA requires the registration consent to come from the person's mobile phone (Swartz *et al.*, 2021). There are some concerns around the consent process when providers use batch registration methods (refer to Section 9.3.2.3 i.ii)).

The maturity of policies at the macro-level was identified as level 5. Various existing policies in South Africa create a supportive policy environment for the design, implementation and scaling of MomConnect (University of Witwatersrand, 2016; Seebregts *et al.*, 2018; Swartz *et al.*, 2021). The policies supporting MomConnect include:

i. The 2012-2016 eHealth Strategy South Africa: the mission of the policy is to "*establish eHealth as an integral part of the transformation and improvement of healthcare services in South Africa*" (Department of Health, 2012, p.8)
ii. The 2014 National Health Normative Standards Framework for Interoperability in eHealth in South Africa: a framework that addresses interoperability of systems and eHealth innovations, which was developed to support the eHealth Strategy (Seebregts *et al.*, 2018).
iii. The 2015-2019 mHealth strategy: the mission of the policy is to "*apply mHealth as an integral part of delivery of health care services*" (Department of Health, 2015a, p.9). the mHealth strategy complements the eHealth Strategy (Seebregts *et al.*, 2016)
iv. The National Health Promotion Policy and Strategy: this policy is based on numerous existing regional and international health declarations that South Africa is part of. The strategy's vision is to provide "*a long and healthy life for all South Africans through the promotion of healthy lifestyle practices and wellness*" (Department of Health, 2015b, p.9).

The maturity of standards & guidelines at the macro-level was identified as level 4. Standards & guidelines were developed to guide the hosting and accessing of MomConnect data (Barron *et al.*, 2018). There are no guidelines for removing inactive users (Peter *et al.*, 2018) for performing batch registrations or using facility/health worker devices (Measure Evaluation, 2016).

The maturity of institutions and their priorities at the macro-level was identified as level 5. MomConnect was a key ministerial initiative to improve maternal and child health from its inception (Barron *et al.*, 2018; Seebregts *et al.*, 2018). Within the World Health Organization (which South

Africa is a member) guideline *Recommendations on Digital Interventions for Health System Strengthening*, maternal health is highlighted as a priority area for targeted digital communication (Ramnund *et al.*, 2021).

South Africa is a member of the United Nations (UN), and the NDOH priorities are aligned with the goals outlined in the UN's millennium development goals and the subsequent 2030 UN SDGs. SDG 3: "*ensure healthy lives and promote well-being for all at all ages*", and the goal's targets 3.1 "*reduce the global maternal mortality ratio*" and 3.2 "*end preventable deaths of newborns and children under 5 years of age*" (United Nations, 2018) are closely aligned with the objectives of MomConnect implying that there would be a higher likelihood of long term macro-level support of MomConnect. One of the goals in the NDOH's Strategic Plan for 2020/21 to 2024/25 is to achieve universal health coverage (National Department of Health, 2020b). MomConnect is an intervention that contributes towards the operationalisation of universal health coverage by ensuring easy access to evidence-based perinatal health information (Livingston Mehl *et al.*, 2018).

iv) MomConnect: Relations & Networks Domain Results

Data relevant to MomConnect's relations & networks sub-domains (i) relationship dynamics, (ii) collaborations, and (iii) evaluation networks were analysed to determine their respective maturity levels. The MomConnect case study results for the relations & networks domain are summarised in Figure 9.8.

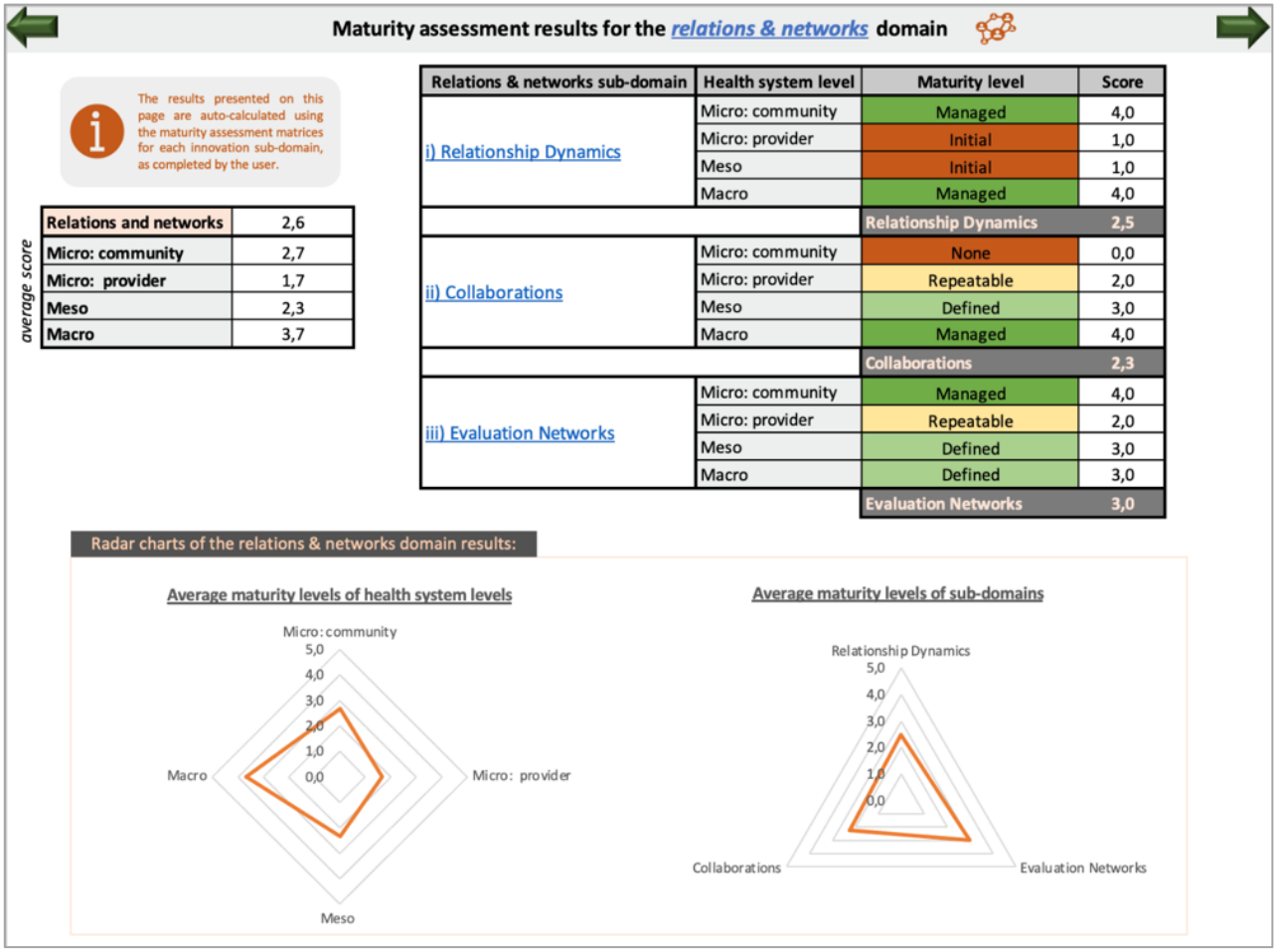

Figure 9.8: Relations & networks domain results for the MomConnect case study

Figure 9.8 shows that the summary maturity score for the relations & networks domain is at level 2,6 *repeatable*. The relations & networks sub-domain that achieved the lowest maturity score was collaborations at 2,3, and the health system level scoring the lowest was the micro-provider level at 1,7. As the average maturity score for this domain is less than 3, general interventions to improve the relations & networks should be developed, focusing on collaborations and relationship dynamics. The following sub-sections present details of the data collected for the relations & networks domain.

iv.i) MomConnect: Relations & Networks Maturity at Micro-Community Level

The average relations & networks maturity score for the micro-community level is level 2,7 repeatable. Table 9.13 provides a summary of the elements supporting the identified micro-community maturity levels for each relations & networks sub-domain.

Table 9.13: MomConnect summary of the relations & networks maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Relationship dynamics	4	The MomConnect helpdesk has created accountability dynamics between community members and health providers and between community members and health management.
Collaborations	0	No clear involvement or engagement with the community.
Evaluation networks	4	There are established evaluation networks that MomConnect users can send their feedback through.

The maturity of relationship dynamics at the micro-community level was identified as level 4. The relationships at the micro-community level are managed through the helpdesk feature of MomConnect. The helpdesk allows MomConnect users to send questions, compliments and complaints and has established accountability dynamics between community members and health providers and between community members and health management (Engelhard *et al.*, 2018).

The maturity of collaborations at the micro-community level was identified as level 0. There was no apparent involvement or engagement with the community outside the facility-based registrations.

The maturity of evaluation networks at the micro-community level was identified as level 4. The evaluation networks present to improve the engagement of community members, the uptake of MomConnect (Haseki, Yoo and Srinivasan, 2019a), inform healthcare improvements (Peter, 2018) and have led to improvements in the quality of healthcare provided to the community (Barron *et al.*, 2018). The evaluation channels that community members can use include (i) a feedback survey that registered MomConnect users are prompted to complete (Haseki, Yoo and Srinivasan, 2019a) and (ii) the compliments and complaints function of the helpdesk, which community members use as an evaluation channel (National Department of Health, 2022c).

iv.ii) MomConnect: Relations & Networks Maturity at Micro-Provider Level

The average relations & networks maturity score for the micro-provider level is level 2,0 repeatable. Table 9.14 summarises of the elements supporting the identified micro-provider maturity levels for each relations & networks sub-domain.

Table 9.14: MomConnect summary of the relations & networks maturity at micro-provider level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Relationship dynamics	1	Insufficient facility management support and unclear supervisory and reporting structures surrounding MomConnect.
Collaborations	2	Little collaboration with health providers and facilities when planning for the scale-up of MomConnect.
Evaluation networks	2	The evaluation networks at the provider level exist but are not always fully functional.

The maturity of relationship dynamics at the micro-provider level was identified as level 1. Within public health facilities, there tends to be hierarchical bureaucracy which could impact the implementation of an intervention (Wolff-Piggott, Coleman and Rivett, 2018). However, this was not identified as an implementation barrier. The challenge was insufficient facility management support, with facility managers needing more clarity on the MomConnect supervisory and reporting structures (Measure Evaluation, 2016). MomConnect was seen as periphery to the integral ANC that professional nurses needed to deliver, which led to the responsibility of registering women onto MomConnect to lower cadres such as health promoters (Wolff-Piggott, Coleman and Rivett, 2018)

The maturity of collaborations at the micro-provider level was identified as level 2. There was little collaboration with health providers and facilities when planning for the scale-up of MomConnect; the tight timeline defined by the minister of health to roll out MomConnect meant there was barely any time to engage with individuals at the health facility level (Ezezika, Varatharajan and Racine, 2020).

The maturity of evaluation networks at the micro-provider level was identified as level 2. There were uncertainties and disparities surrounding reporting among providers (Measure Evaluation, 2016). Facility managers and, subsequently, health providers did not always receive feedback on the status of MomConnect registrations in their respective facilities, the lack of feedback could have negative implications on the continued championing of MomConnect (Wolff-Piggott, Coleman and Rivett, 2018). Even if the facility manager received reports, there were not always clear plans for increasing MomConnect registration (Measure Evaluation, 2016). In one investigation, it was found that only 54% of health facility supervisors received registration reports (Measure Evaluation, 2016). The help desk feedback, both compliments and complaints, associated with a facility was sent to the manager of the health facility; managers were expected to respond to the feedback within ten days with a report describing the action taken (Barron *et al.*, 2018; Pillay and Motsoaledi, 2018).

iv.iii) MomConnect: Relations & Networks Maturity at Meso-Level

The average relations maturity score for the meso-level is level 2,3 repeatable. Table 9.15 summarises the elements supporting the identified meso-maturity levels for each relations & networks sub-domain.

Table 9.15: MomConnect summary of the relations & networks maturity at meso-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Relationship dynamics	1	Power dynamics between the different health system tiers were an enabling factor. However, there were unclear supervisory structures relating to MomConnect at the district and provincial levels.
Collaborations	3	Established collaborations between the meso- and macro-levels enabled implementation.
Evaluation networks	3	Established evaluation networks in which reports on MomConnect are frequently sent to provincial departments of health.

The maturity of relationship dynamics at the meso-level was identified as level 1. Local authorities in the district or provincial departments of health oversee the delivery of ANC in public health facilities, and the NDOH oversees the provincial departments (Wolff-Piggott, Coleman and Rivett, 2018). The power dynamics between the different health system tiers (national, province and district) enabled the collective engagement with MomConnect (Peter *et al.*, 2018). With collaborations taking place between the different health system tiers. There are, however, unclear supervisory structures relating to MomConnect at the district and provincial levels; this could be improved by developing standard operating procedures for supervisory structures (Measure Evaluation, 2016).

The maturity of collaborations at the meso-level was identified as level 3. The collaborations between the meso- and macro-levels are established. The meso-level collaborations and engagements with the NDOH facilitate scaling up MomConnect.

The maturity of evaluation networks at the meso-level was identified as level 3. There are established evaluation networks for which data on registrations are compiled into weekly reports and sent to the provincial departments of health (Peter *et al.*, 2018). When complaints submitted through the helpdesk remain unresolved, they are escalated to the provincial department of health managers (Barron *et al.*, 2018). While there are established evaluation networks between provincial and national departments of health, the meso-level did not provide regular feedback to the micro-provider level on the MomConnect registrations (Wolff-Piggott, Coleman and Rivett, 2018).

iv.iv) MomConnect: Relations & Networks Maturity at Macro-level

The macro-level's average relations & networks maturity score is level 3,7 defined. Table 9.16 summarises the elements supporting the identified macro-maturity levels for each relations & networks sub-domain.

Table 9.16: MomConnect summary of the relations & networks maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Relationship dynamics	4	Leadership and oversight provided by the highest levels in the NDOH and the good relationships between the various donors enabled the implementation of MomConnect.
Collaborations	4	Collaborations existed between a wide range of stakeholders; these collaborations were monitored by the task team set up to implement MomConnect.
Evaluation networks	3	The macro-level can easily evaluate the progress of MomConnect through the already established DHIS2 system. Additionally, a report outlining the progress of MomConnect was frequently circulated to members of the task team.

The maturity of relationship dynamics at the macro-level was identified as level 4. The bureaucratic nature of the NDOH (Heales and Green, 2016) did not hinder the implementation of MomConnect. Instead, the leadership and oversight provided by the highest levels in the department of health were an enabling factor to MomConnect's implementation (Barron *et al.*, 2018). Good relationship dynamics among the various donors involved with MomConnect enabled funding continuity and increased accountability (Swartz *et al.*, 2021).

The maturity of collaborations at the macro-level was identified as level 4. There were collaborations between the macro-level and parastatals, the private sector, NGOs and academic organisations (Seebregts *et al.*, 2016). The broad mix of collaborators enabled the technical architecture development, significant upfront investment and cost reductions for SMSs (Seebregts *et al.*, 2016; Peter *et al.*, 2018; Swartz *et al.*, 2021). Regular task team meetings monitored these collaborations during scale-up (Barron *et al.*, 2018). The task team had political and senior NDOH support, which meant that decisions made were more likely to be executed; the task team also ensured that the many collaborators were held accountable (Barron *et al.*, 2018).

The maturity of evaluation networks at the macro-level was identified as level 3. MomConnect has been integrated with the DHIS2, the existing system that NDOH personnel already used to monitor and evaluate different programs (Seebregts *et al.*, 2016). The DHIS2 evaluation network allows the macro-level to easily monitor and evaluate MomConnect's implementation through coverage rates for different provinces, districts and facilities (Barron *et al.*, 2018; Seebregts *et al.*, 2018). In addition to the more passive evaluation network through DHIS2, aggregate data are analysed against performance indicators. They are made available in the form of a report which is actively circulated to the members of the MomConnect task team (Seebregts *et al.*, 2016).

v) MomConnect: Knowledge Domain Results

Data relevant to MomConnect's knowledge sub-domains (i) dissemination & diffusion, (ii) knowledge base & capacity, and (iii) education & training were analysed to determine their respective maturity levels. The MomConnect case study results for the knowledge domain are summarised in Figure 9.9.

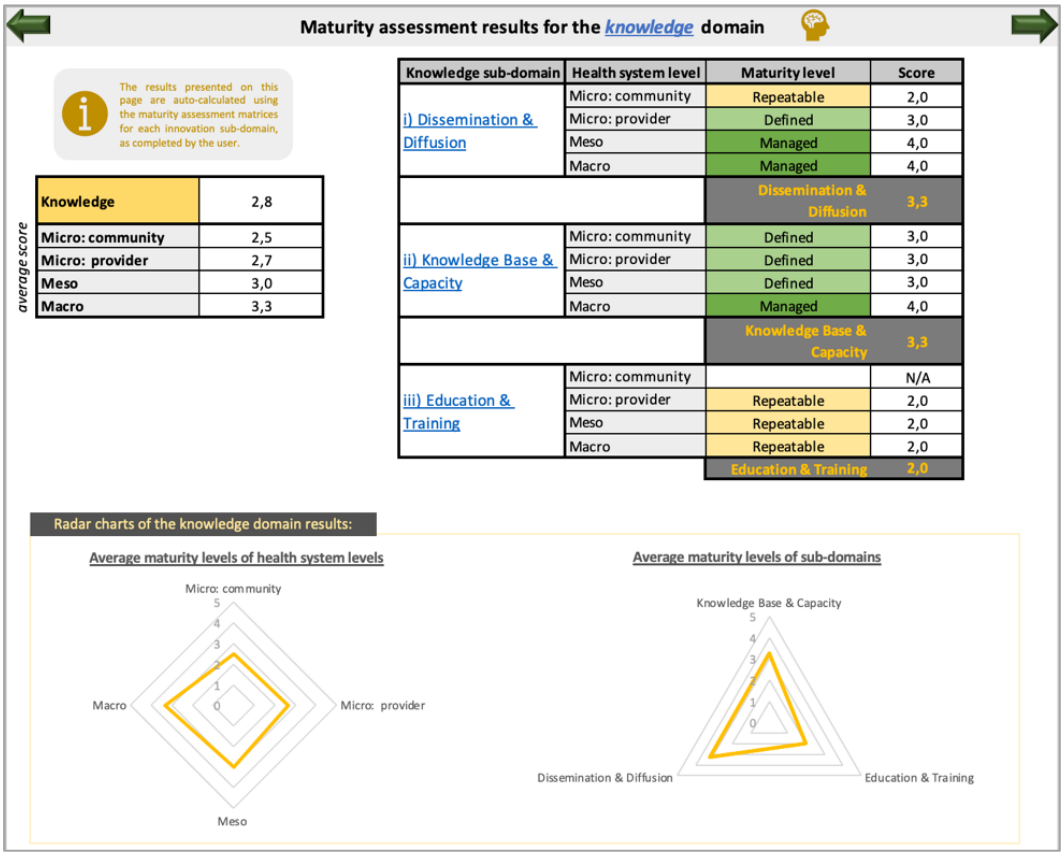

Figure 9.9: Knowledge domain results for the MomConnect case study

As Figure 9.9 shows, the summary maturity score for the knowledge domain is at level 2,8 *repeatable*. The knowledge sub-domain that achieved the lowest maturity score, education & training, at 2,0 and the health system level scoring the lowest was the micro-community level at 2,5. Both of these areas should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the knowledge domain.

v.i) MomConnect: Knowledge Maturity at Micro-Community Level

The average knowledge maturity score for the micro-community level is level 2,5 repeatable. Table 9.17 summarises the elements supporting the identified micro-community maturity levels for each knowledge sub-domain.

Table 9.17: MomConnect summary of the knowledge maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Dissemination & diffusion	**2**	While there is good coverage of MomConnect among pregnant women, the dissemination & diffusion processes are not formalised. There have been calls for formalising the dissemination process to improve community awareness.
Knowledge base & capacity	**3**	The knowledge base of community members enabling the use of MomConnect is good, with the majority of people able to use a mobile phone. The complete set of features associated with MomConnect was not always known (e.g., helpdesk function).
Education & training	**N/A**	The maturity of education & training at the micro-community level was not assessed because this sub-domain was not deemed applicable for the uptake of MomConnect.

The maturity of dissemination & diffusion at the micro-community level was identified as level 2. MomConnect boasts a high coverage, with about two-thirds of pregnant women registering for MomConnect (Livingston Mehl *et al.*, 2018; Banning-Lover, 2020). The community awareness of MomConnect is equitably distributed, with one study estimating that 44% of users are from low-income households (Heales and Green, 2016). This implies that a good amount of dissemination or diffusion is happening at the micro-community level. However, these processes have not been formalised. One study found that 30% of ANC attendees had not been offered MomConnect registration when attending their first ANC visit (Heales and Green, 2016). MomConnect users have reported that they disseminate and advocate for their friends to request MomConnect registration when they attend health facilities (Heales and Green, 2016; Skinner *et al.*, 2018; Ezezika, Varatharajan and Racine, 2020). There is a general call for the MomConnect dissemination process to be formalised through broad advertisement of the service via signs in facilities, television or radio adverts (Skinner *et al.*, 2018; Ezezika, Varatharajan and Racine, 2020)

The maturity of the knowledge base & capacity sub-domain at the micro-community level was identified as level 3. The knowledge required for community members to use the innovation includes the ability to use their phone, particularly the USSD and SMS features, which community members generally had knowledge of (Heales and Green, 2016; Peter *et al.*, 2018). However, there were health workers who perceived that some community members were not able to use their phones well (Wolff-Piggott, Coleman and Rivett, 2018). There is also a lack of knowledge on the MomConnect helpdesk functionality, with users reporting that they could not ask personalised questions on MomConnect, which one can do through the helpdesk (Mogoba *et al.*, 2019).

v.ii) MomConnect: Knowledge Maturity at Micro-Provider Level

The average knowledge maturity score for the micro-provider level is level 3,0 defined. Table 9.18 summarises the elements supporting the identified micro-provider maturity levels for each knowledge sub-domain.

Table 9.18: MomConnect summary of the knowledge maturity at micro-provider level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Dissemination & diffusion	**3**	MomConnect is offered in over 95% of facilities. The dissemination & diffusion channels were the official MomConnect launch and subsequently through health workers sharing the information with their peers. There have been cases of health providers not having adequate awareness of MomConnect and its contents.
Knowledge base & capacity	**3**	The knowledge base of health providers enabling the use of MomConnect is good, with providers being able to use the USSD functionality of mobile phones and having training on how to calculate the gestational age.
Education & training	**2**	Training on MomConnect was provided; however, it was deemed inadequate, with little follow-up training and providers having to orientate one another on MomConnect.

The maturity of dissemination & diffusion at the micro-provider level was identified as level 4. MomConnect is offered by over 95% of health facilities (Heales and Green, 2016; Pillay and Motsoaledi, 2018), implying that there has been a successful dissemination or diffusion process surrounding MomConnect. The dissemination or diffusion channels have been through the official launch of MomConnect or peers, with very few people recalling MomConnect posters being present at facilities (Measure Evaluation, 2016). There were reports of health providers not promoting

MomConnect because they did not have adequate awareness of MomConnect and its contents (Ezezika, Varatharajan and Racine, 2020).

The maturity of the knowledge base & capacity sub-domain at the micro-provider level was identified as level 3. Similar to the micro-community level, the mobile phone technologies (USSD and SMS) used by MomConnect are familiar to and commonly used by health providers at the micro-provider level (Wolff-Piggott, Coleman and Rivett, 2018). If a health provider had to use the woman's phone to register her, the registration process would take longer as the provider would have to familiarise themselves with the phone (Wolff-Piggott, Coleman and Rivett, 2018). In addition to the knowledge of basic mobile phone use, the health provider needs to know how to calculate the gestational age correctly, and that registration should happen at the woman's first ANC visit (Measure Evaluation, 2016; Mogoba *et al.*, 2019)

The maturity of education & training at the micro-provider level was identified as level 2. Most health providers have a midwifery qualification (Ramnund *et al.*, 2021) which supports the implementation of MomConnect (Skinner *et al.*, 2018). In addition to the health qualifications, simple training material focusing on using USSD and the registration process was developed (Seebregts *et al.*, 2018). The training was perceived to be inadequate by the health providers; there was minimal follow-up training; the majority of new personnel were trained by other health providers in the facility, which is a challenge when there are high rates of staff turnover (Heales and Green, 2016; Measure Evaluation, 2016; Ezezika, Varatharajan and Racine, 2020). The lack of standardised training practices and training not being up-to-date were raised as challenges (Heales and Green, 2016; Ezezika, Varatharajan and Racine, 2020).

v.iii) MomConnect: Knowledge Maturity at Meso-Level

The average knowledge maturity score for the meso-level is level 3,0 defined. Table 9.19 summarises the elements supporting the identified meso-maturity levels for each knowledge sub-domain.

Table 9.19: MomConnect summary of the knowledge maturity at meso-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Dissemination & diffusion	**4**	Dissemination & diffusion processes at the provincial level were managed and formalised through provincial roadshows.
Knowledge base & capacity	**3**	At the meso-level, the knowledge base required for the implementation of MomConnect is basic descriptive statistical knowledge (for the provincial monitoring of MomConnect) and an understanding of the purpose of MomConnect. Most stakeholders at the meso-level are medical doctors or have years of public health experience. Therefore, there is an existing knowledge base at the meso-level.
Education & training	**2**	Some meso-level personnel received the operational training of MomConnect. This training did not cover reporting or how supervision should be undertaken.

The maturity of dissemination & diffusion at the meso-level was identified as level 4. Dissemination of MomConnect to the meso-level was primarily through the launch of and the subsequent provincial roadshows undertaken by the minister of health for MomConnect (Seebregts *et al.*, 2018).

The maturity of the knowledge base & capacity sub-domain at the meso-level was identified as level 3. Most of the meso-level stakeholders in the Gauteng Department of Health are health professionals

or have relevant public health experience and training. The current Gauteng head of health is a medical doctor with many years of experience in the public health sector (Pheto, 2022). Thus, the meso-level stakeholders would have the relevant knowledge base to understand the purpose of MomConnect.

The maturity of the education & training sub-domain at the meso-level was identified as level 2. Some meso-level stakeholders did receive training on MomConnect; the training was the same as that provided to the micro-health provider level, which did not cover reporting or how supervision should be undertaken to support the process (Measure Evaluation, 2016).

v.iv) MomConnect: Knowledge Maturity at Macro-level

The average knowledge maturity score for the macro-level is level 3,3 defined. Table 9.20 summarises the elements supporting the identified macro-maturity levels for each knowledge sub-domain.

Table 9.20: MomConnect summary of the knowledge maturity of MomConnect at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Dissemination & diffusion	4	There was good awareness of MomConnect among macro-level personnel due to the high-level campaign carried out by the macro-level.
Knowledge base & capacity	4	The knowledge base & capacity of the macro-level was managed by ensuring that personnel with a broad range of knowledge were involved in the development and implementation of MomConnect.
Education & training	2	No formal training or educational sessions were provided to the macro-level personnel.

The maturity of the dissemination & diffusion sub-domain at the macro-level was identified as level 4. MomConnect was led by the macro-level; therefore, there was good awareness of MomConnect among the macro-level stakeholders. The minister of health launched MomConnect through a high-profile campaign, which garnered significant media coverage (Barron *et al.*, 2018; Haseki, Yoo and Srinivasan, 2019b).

The maturity of the knowledge base & capacity sub-domain at the macro-level was identified as level 4. The task team set up to manage MomConnect covered a broad range of knowledge required for the successful development, implementation and scale-up of MomConnect. This included technical expertise, public health professionals, trainers, mobile network operators, academic institutions and strategists (Heales and Green, 2016; Seebregts *et al.*, 2016).

The maturity of the education & training sub-domain at the macro-level was identified as level 2. There was no formal training or educational sessions provided to the macro-level stakeholders. As discussed in the knowledge base & capacity domain, the necessary skills were brought in to enable the development and implementation of MomConnect. However, the longer-term availability of these skills is uncertain (Seebregts *et al.*, 2018), which is where macro-level training would be beneficial.

vi) MomConnect: Actors Domain Results

Data relevant to MomConnect's actors sub-domains (i) culture, (ii) motivations, and (iii) beliefs & attitudes, were analysed to determine their respective maturity levels. The MomConnect case study results for the actors domain are summarised in Figure 9.10.

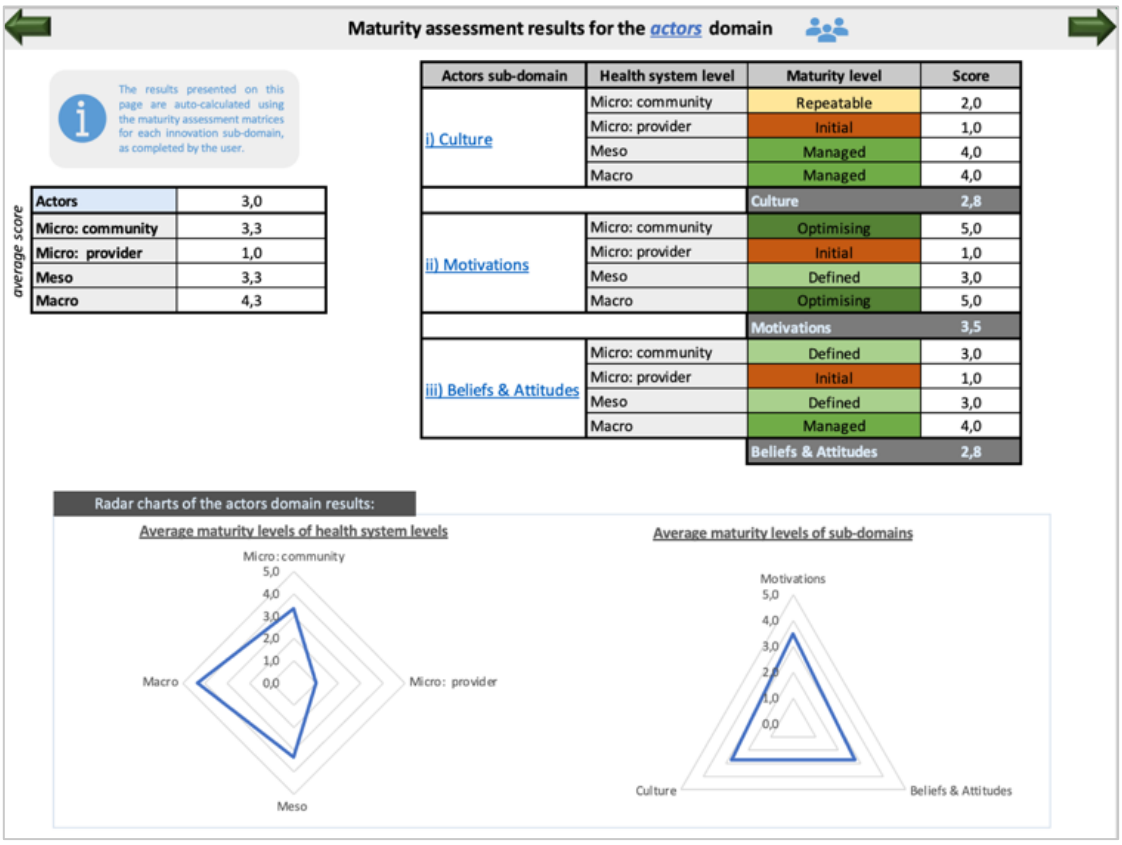

Figure 9.10: Innovation domain results for the MomConnect case study

As Figure 9.10 shows, the summary maturity score for the actors domain is at level 3,0 *defined*. The actors sub-domain that achieved the lowest maturity score was for beliefs & attitudes, and culture both at 2,8 and the health system level scoring the lowest was the micro-provider at 1,0. All three of these areas should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the actors domain.

vi.i) MomConnect: Actors Maturity at Micro-Community Level

The average actors maturity score for the micro-community level is level 3,3 defined. Table 9.21 summarises the elements supporting the identified micro-community maturity levels for each actors sub-domain.

Table 9.21: MomConnect summary of the actors maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Culture	**2**	Stigma surrounding HIV was a hindrance to some HIV-positive community members who were worried that MomConnect would expose their status. Late ANC initiation was a barrier to some community members accessing MomConnect.
Motivations	**5**	No disincentives were identified for the micro-community level. Incentives include feelings of empowerment, support and connection by having access to evidence-based information that is tailored according to the gestational period, all of which create motivation to utilise MomConnect.
Beliefs & attitudes	**3**	Community members had positive attitudes towards MomConnect. MomConnect is perceived as accurate and is trusted by the community.

The maturity of the culture sub-domain at the micro-community level was identified as level 2. At the micro-community level, a hindrance that health providers cited was HIV-positive women worried that their HIV status would be exposed if they registered on MomConnect (Wolff-Piggott, Coleman and Rivett, 2018). There is a stigma associated with HIV (pre-emptive, enacted and internalised stigma), which results in persons living with HIV concealing their status (MacLean and Wetherall, 2021). A cultural barrier that hinders the community's accessing MomConnect is the delayed initiation of ANC due to anxieties about HIV testing, fear of miscarriage, underestimating the importance of ANC, and being underage or unmarried (Woldesenbet *et al.*, 2021).

The maturity of the motivations sub-domain at the micro-community level was identified as level 5. MomConnect has no direct disincentives, there are no costs to the community members who want to register, and the registration process is easy (Seebregts *et al.*, 2016; Skinner *et al.*, 2018). The micro-community level incentives associated with MomConnect include feelings of support, empowerment, trust, feeling connected and engaged due to the personalisation according to gestational age (Barron *et al.*, 2018; Livingston Mehl *et al.*, 2018; Peter, 2018; Peter *et al.*, 2018; Skinner *et al.*, 2018; Kabongo *et al.*, 2020; Trafford *et al.*, 2020). Pregnant women tend to be highly motivated to obtain health information (Peter, 2018). The motivation levels surrounding MomConnect are highlighted by women wanting to have the MomConnect messages sent for longer or more frequently (Heales and Green, 2016; Peter, 2018; Skinner *et al.*, 2018).

The maturity of the beliefs & attitudes sub-domain at the micro-community level was identified as level 3. There were generally positive attitudes towards MomConnect, with MomConnect being perceived as useful and valuable, enhancing decision-making (Measure Evaluation, 2016; Coleman J and Xiong K, 2017; Peter *et al.*, 2018; Trafford *et al.*, 2020). MomConnect, in conjunction with information received from health providers, is viewed as accurate and is trusted by women (Skinner *et al.*, 2018; Trafford *et al.*, 2020). Concerns were raised around entering personal identifying information, with concerns that the information might not remain private or that sensitive health information might be used for fraudulent activities (Wolff-Piggott, Coleman and Rivett, 2018).

vi.ii) MomConnect: Actors Maturity at Micro-Provider Level

The average actors maturity score for the micro-provider level is level 1,0 *initial*. Table 9.22 summarises the elements supporting the identified micro-provider maturity levels for each actors sub-domain.

Table 9.22: MomConnect summary of the actors maturity at micro-provider level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Culture	1	Micro-provider level is resistant to the innovation due to existing work-burden and time pressures.
Motivations	1	Provider level disincentives include unreliable USSD and lack of access to MomConnect-related information. There were no clear provider level motivations.
Beliefs & attitudes	1	Providers perceived MomConnect as a peripheral activity, an added burden, having no direct benefits to their work and as being outside the scope of their work.

The maturity of the culture sub-domain at the micro-provider level was identified as level 1. The culture at the provider level was resistant to the innovation, mainly due to the added time pressures that MomConnect added to health providers' day-to-day ANC operations (Barron *et al.*, 2018; Skinner *et al.*, 2018).

The maturity of the motivations sub-domain at the micro-provider level was identified as level 1. Numerous disincentives have been identified at the micro-provider level, including unreliable USSD sessions and subsequent time-outs impacting motivation, lack of access to the information that the MomConnect users got access to (Ezezika, Varatharajan and Racine, 2020) and the existing time pressures faced by the health providers which MomConnect was adding to (Barron *et al.*, 2018),

The maturity of the beliefs & attitudes sub-domain at the micro-provider level was identified as level 1. The health providers saw MomConnect as a peripheral activity or an added burden (Wolff-Piggott, Coleman and Rivett, 2018; Ezezika, Varatharajan and Racine, 2020). The health providers acknowledged the benefits of MomConnect for pregnant women but did not perceive there to be direct benefits to their work (Measure Evaluation, 2016; Wolff-Piggott, Coleman and Rivett, 2018). Furthermore, health providers, particularly nurses, did not perceive the registration process, which is mainly data entry, to be in the scope of their work (Wolff-Piggott, Coleman and Rivett, 2018).

vi.iii) MomConnect: Actors Maturity at Meso-Level

The average actors maturity score for the meso-level is level 3,3 *defined*. Table 9.23 summarises the elements supporting the identified meso-maturity levels for each actors sub-domain.

Table 9.23: MomConnect summary of the actors maturity at meso-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Culture	4	No resistance to MomConnect and a general acceptance within the meso-level.
Motivations	3	At the meso-level, the engagements performed by the macro-level incentivised the meso-level acceptance of MomConnect.
Beliefs & attitudes	3	Meso-level personnel had positive attitudes towards MomConnect.

The maturity of the culture sub-domain the meso-level was identified as level 4. There was no reported resistance to the innovation at the meso-level, and with the national level push, there was a good acceptance of MomConnect at the meso-level. The maturity of motivations at the meso-level was identified as level 3. NDOH promoting MomConnect ensured good engagement among meso-level stakeholders (Ezezika, Varatharajan and Racine, 2020). The maturity of the beliefs & attitudes

sub-domain at the meso-level was identified as level 3. Positive attitudes towards MomConnect were established, and no pre-existing beliefs were hindering the implementation of MomConnect.

vi.iv) MomConnect: Actors Maturity at Macro-level

The average actors maturity score for the macro-level is level 4,3 managed. Table 9.24 summarises the elements supporting the identified macro-maturity levels for each actors sub-domain.

Table 9.24: MomConnect summary of the actors maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Culture	4	The organisational culture at NDOH enabled the implementation of MomConnect.
Motivations	5	Incentives include the potential for MomConnect to improve maternal and neonatal health indicators and the low risks associated with developing MomConnect.
Beliefs & attitudes	4	The macro-level attitudes were generally positive, and there was noted enthusiasm surrounding MomConnect.

The maturity of the culture sub-domain at the macro-level was identified as level 4. The organisational culture at the macro-level allowed for the acceptance and successful integration of MomConnect into the NDOH. The maturity of motivations at the macro-level was identified as level 5. The incentives surrounding MomConnect include its ability to provide pregnant women with evidence-based information that could reduce maternal and neonatal mortality, increasing the possibility of South Africa achieving the United Nations' goals (Swartz *et al.*, 2021). Furthermore, during its development, MomConnect used existing components, reducing the development and scale-up risks (Seebregts *et al.*, 2016).

The maturity of the beliefs & attitudes sub-domain at the macro-level was identified as level 4. At the macro-level, there was a great deal of enthusiasm surrounding MomConnect with perceptions of value among NDOH personnel and donors (Barron *et al.*, 2018; Swartz *et al.*, 2021).

9.3.2.4 MomConnect Summary Results

The summary of the results of the assessment of MomConnect is shown in Figure 9.11. The domains with the highest scores are institutions at 4,3 – highlighting South Africa's supportive policy and legislative environment and resources at 3,6 – highlighting that the innovation was designed for use in an LMIC setting. The health system level with the highest score is the macro-level at 3,9 – which emphasises that the macro-level was a key driving force in the innovation's success. The lowest maturity scores are observed in the relations & networks domain at 2,6 and the micro-provider health system level at 2,2.

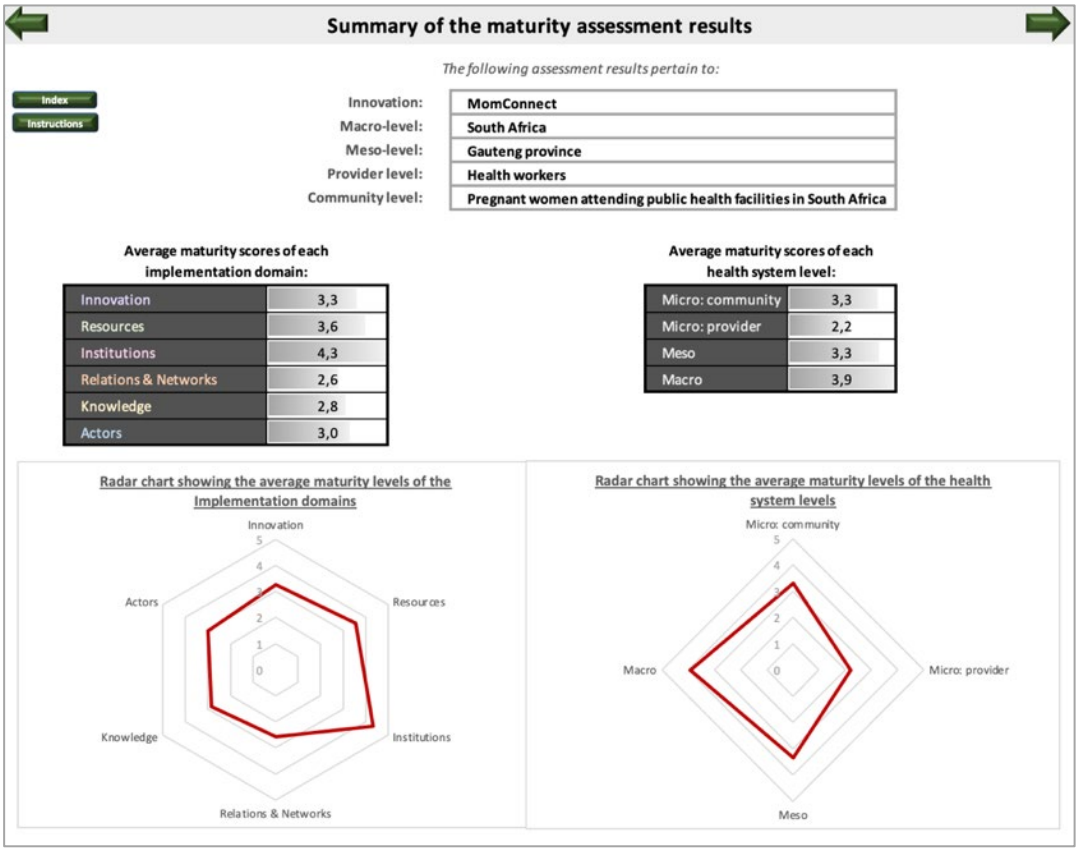

Figure 9.11: MomConnect Summary Results

9.3.3 COVID Alert

The second case study conducted using the final HII-MM is on implementing the evidence-based innovation COVID Alert in South Africa. COVID Alert forms part of the South African government's digital COVID-19 support platform; it is an exposure notification application that alerts an individual when they have been in close contact with someone who has tested positive for COVID-19 (National Department of Health, 2022a).

9.3.3.1 Defining the COVID Alert Case Study

As described in the case study protocol (Chapter 2, Section 2.3.3.2), the first step is to define the chosen case study. In the following sub-sections, the various aspects of the general considerations user interface are described, (i) the COVID Alert innovation is described, (ii) the specifics of the implementation process are outlined, and (iii) the health system into which the COVID Alert innovation is implemented is described.

i) COVID Alert General Considerations: Innovation

COVID Alert was developed to complement South Africa's manual contract tracing efforts (Modisenyane *et al.*, 2021). Contact tracing is a control measure to prevent the spread of infectious diseases (i.e., COVID-19). The chain of transmission is broken by effectively identifying and isolating individuals who test positive for COVID-19 and quarantining their close contacts (Taylor *et al.*, 2021).

COVID Alert is a mHealth smartphone application based on the Google Apple Exposure Notification System; it sends individuals a push notification if they have been in contact with a COVID-19 positive individual for 15 minutes or more (Modisenyane *et al.*, 2021). Following an exposure push notification, messaging is provided on how to prevent spreading COVID-19 further, monitor COVID-19 symptoms and access healthcare if needed (Modisenyane *et al.*, 2021; National Department of Health, 2022a).

ii) COVID Alert General Considerations: Implementation Process

The majority of the data collected for the case study was collected in early 2021. During this time, COVID Alert was in the inter-implementation stage, as COVID Alert was launched in September 2020. The stakeholders involved with the implementation of COVID Alert include: (i) the recipients of the innovations, i.e., the South African population, (ii) the implementation leads, i.e., the NDOH, (iii) the developer of the application, i.e., Discovery using technology developed by Google and Apple, (iv) the laboratories that perform COVID-19 tests and provide the individuals who test positive with a unique pin to enter into the application, (v) Banking Association of South Africa, and (vi) mobile network operators (National Department of Health, 2020a).

COVID Alert's functions include: (i) enabling users to monitor their exposure risk, (ii) guiding close contacts on steps that should be taken, and (ii) allowing COVID-19 positive individuals to anonymously notify their close contacts (National Department of Health, 2022a). COVID Alert operates on an opt-in basis and is only compatible with smartphones. Users download COVID Alert from the Apple App Store or the Google Play Store free of charge. COVID Alert is under 3 *MB* to download, and once downloaded, it is zero-rated by the major South African mobile network operators. For COVID Alert to function, the user must enable Bluetooth and notifications. COVID Alert uses Bluetooth to exchange random codes with other users who come within a 2-metre radius for 15 minutes or longer. These random codes are stored on both mobile phones for 16 days. If a user tests positive for COVID-19, they receive a unique code to enter into COVID Alert. Any COVID Alert users with whom the positive individual had been in close contact over the past 16 days will receive an exposure notification. The notification includes relevant information on what to do next to break the chain of transmission and optimise their health (Botes, 2020; Business Insider SA, 2020; Bosman, 2021; National Department of Health, 2022a).

iii) COVID Alert General Considerations: Health System Levels

The macro-health system level assessed for the COVID Alert case study is the South African NDOH. The meso- and micro-provider levels are not assessed for this case study. COVID Alert does not necessitate a health provider to provide the innovation; COVID Alert is directly accessible to the community. Furthermore, the launch and implementation of COVID Alert were driven by the NDOH, with seemingly little involvement from sub-national levels, which is highlighted by little information available to assess a sub-national level. The micro-community level assessed in the COVID Alert case study is a subset of the general population: university students attending Stellenbosch University (SU).

9.3.3.2 COVID Alert Data Collection

The data sources used to complete the COVID Alert case study comprises a mix of academic and grey literature, with a detailed survey[19]. The literature sources include (i) press releases, (ii) news articles, (iii) government websites, (iv) mathematical models, and (v) rapid reviews. The methodology followed to complete the survey is discussed further in Appendix J Section J.3 a). The objective of the COVID Alert survey was to gain an understanding of the micro-community levels' perceived barriers and facilitators to the use of the COVID Alert application. The survey's target population consists of SU students enrolled in under- or postgraduate studies. The sample size was determined by the *access to subjects* factor discussed by Glasow (2005); a total of 1 774 students completed the survey. The survey was developed using the HII-MM and distributed using the online platform Checkbox® via electronic mail. The comprehensive survey questions is presented in Appendix J Section J.3 b). The survey responses were coded and analysed, and the results are reported in the following sub-section. The descriptive results of the survey questions are presented in Appendix J Section J.3 c).

9.3.3.3 COVID Alert Case Study Results

Maturity levels are decided on by using the maturity assessment matrix. Once collected, the data are summarised and categorised according to the HII-MM domains, sub-domains and health system levels. The categorised data are then analysed to establish the maturity score for each sub-domain and at each health system level. The maturity results for each domain are described in the following sub-sections.

i) COVID Alert: Innovation Domain Results

Data relevant to COVID Alert's innovation sub-domains (i) design & functionality, (ii) supporting evidence, and (iii) ethics & equity were analysed, and the respective maturity levels were determined. The COVID Alert case study results for the innovation domain are summarised in Figure 9.12.

[19] A survey is a quantitative data collection method in which data from a sample population are systematically gathered to infer attributes about the larger population from which the sample was taken (Groves *et al.*, 2009).

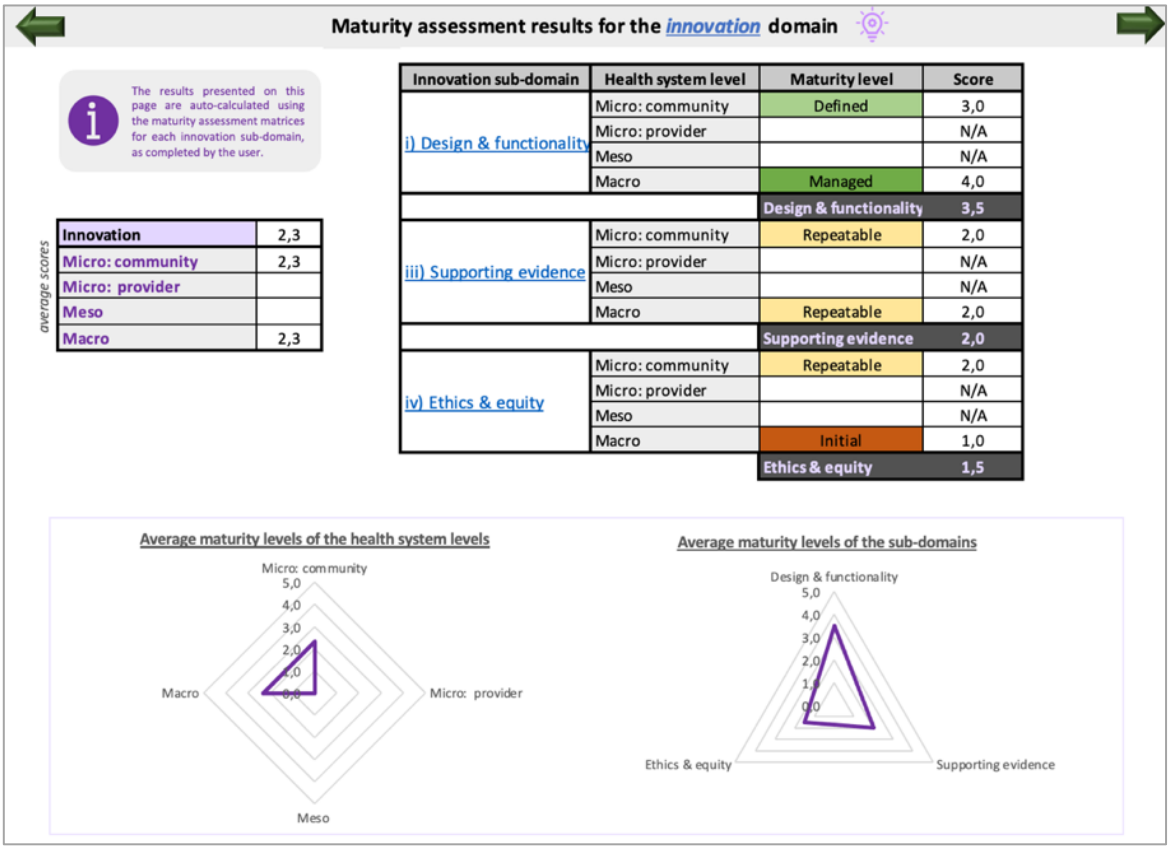

Figure 9.12: Innovation domain results page for the COVID Alert case study

Figure 9.12 shows that the summary maturity score for the innovation domain is at level 2,3 *repeatable*. The innovation sub-domain that achieved the lowest maturity score was ethics & equity at 2,0; this area should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the innovation domain.

i.i) COVID Alert: Innovation Maturity at Micro-Community Level

The average innovation maturity score for the micro-community level is level 2,3 *repeatable*. Table 9.25 summarises the elements supporting the identified micro-community maturity levels for each innovation sub-domain.

Table 9.25: COVID Alert summary of the innovation maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Design & functionality	**3**	COVID Alert is interoperable with the student's socio-demographics, particularly regarding language, technological literacy and cell phone penetration. Additionally, COVID Alert's functionality contributes to the wants and needs of students to return to in-person learning.
Supporting evidence	**2**	There is little real-world evidence supporting the benefits of digital contact tracing. However, there are mathematical studies that show the potential benefits of digital contact tracing provided that there is sufficient uptake.
Ethics & Equity	**2**	Ethical considerations are at the forefront of COVID Alert, with the application ensuring anonymity and confidentiality. However, the ethical features of the application are not well understood by the community.

The maturity of COVID Alert's design & functionality at the micro-community level was identified as level 3. COVID Alert is compatible with the socio-demographics of the SU students. The language used in COVID Alert is English, and SU is a multilingual institution using three languages, Afrikaans, English and isiXhosa (Stellenbosch University, 2021c). English is used as a minimum in SU, as acknowledged in the SU Language Policy "*Speakers of the various South African languages often use English to communicate with one another, and English has significant academic, professional and international value. Therefore, SU uses English routinely, but not exclusively, in its academic, administrative, professional and social contexts.*" (Stellenbosch University, 2022, p. 4). The home language of the majority of students enrolled in SU is English at 47,9% (Stellenbosch University, 2021b), which is mirrored by the survey results in which 44,4% of respondents identified English as their home language. Furthermore, a high proportion of students have a mobile phone with Bluetooth capabilities and the ability to download applications; the coverage, as estimated from the survey, is 98,7%.

Technological literacy of the students supports COVID Alert, with 98,7% of respondents having at least one application downloaded on their cell phones. When considering the community needs, one aspect covered was the need to return to in-person classes. If used by enough people, COVID Alert could contribute by reducing transmission. This was raised in the survey results by 753 respondents (42,4%). Remote teaching and learning exposed digital infrastructure inequities, leading to increased mental health issues and reduced epistemic access (Czerniewicz *et al.*, 2020; McKenna, 2021).

The maturity of COVID Alert's supporting evidence at the micro-community level was identified as level 2. There is evidence supporting the use of digital contact tracing applications for epidemic control by enhancing COVID-19 contact tracing (Ferretti *et al.*, 2020; World Health Organization, 2020b). The evidence is mainly from modelling studies with little evidence of the effectiveness of these applications in real-world settings (Anglemyer *et al.*, 2020). In a modelling study performed on the impact of COVID Alert, the authors concluded that the uptake of COVID Alert by at least 30%, combined with other control measures, could reduce the peak number of infections (Kinyili, Munyakazi and Mukhtar, 2022).

The maturity of COVID Alert's ethics & equity at the micro-community level was identified as level 2. At the community level, COVID Alert is equitably available due to the beforementioned high coverage of phones able to download applications. COVID Alert was designed ethically with features to protect the user's identity and security at all times (National Department of Health, 2022a). The application does not track a person's location, or require any personally identifying information (National Department of Health, 2022a). Even though these ethical solutions are in place, they are not properly understood by the community. This is highlighted by 1 009 survey respondents believing that COVID Alert tracks a person's location instead of using Bluetooth.

i.ii) COVID Alert: Innovation Maturity at Macro-level

The average innovation maturity score for the macro-level is level 2,3 ***defined***. Table 9.26 summarises the elements supporting the identified macro-maturity levels for each innovation sub-domain.

Table 9.26: COVID Alert summary of the innovation maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Design & functionality	4	COVID Alert was developed to address South Africa's need to reduce the high resource burden of performing manual contact tracing and to reduce pressures on the health system by breaking the chain of transmission.
Supporting evidence	2	There is insufficient real-world evidence specific to South Africa showing the impact that digital contact tracing applications such as COVID Alert, have on reducing the burden on the health system.
Ethics & Equity	1	COVID Alert has been designed in an ethical manner, it does not collect personal identifying data, nor does it track a user's location. However, COVID Alert has not been equitably designed for the South African population as a whole, COVID Alert only caters to individuals who have smart phones.

The maturity of COVID Alert's design & functionality sub-domain at the macro-level was identified as level 4. As per guidance from the WHO, South Africa adapted the "*test, trace and isolate*" strategy, which was complimented by the introduction of COVID Alert (Modisenyane *et al.*, 2021, p. 32). COVID Alert contributes to this strategy by contributing to the contact tracing process, relieving some of the burdens on human resources when performing manual contact tracing. Furthermore, COVID Alert is interoperable with the meso-level needs to contain and mitigate the spread of COVID-19 and to reduce the burden and disruptions to the health system (Pillay *et al.*, 2022).

The maturity of COVID Alert's supporting evidence at the macro-level was identified as level 2. As previously discussed, evidence supports the effectiveness of digital contract applications; however, this evidence tends to be limited to modelling studies rather than real-world studies. The maturity of COVID Alert's ethics & equity at the macro-level was identified as level 1. As previously mentioned, COVID Alert has been built ethically, ensuring users' privacy and safety. However, there are gaps when considering the equity of COVID Alert for the general population. Smartphone penetration in South Africa is approximately 51%, with smartphone ownership higher among younger individuals who earn higher incomes (Silver and Johnson, 2018).

ii) COVID Alert: Resources Domain Results

Data relevant to COVID Alert's resources sub-domains (i) infrastructure, services & physical resources, (ii) human resources, and (iii) financial resources were analysed to determine their respective maturity levels. The COVID Alert case study results for the resources domain are summarised in Figure 9.13.

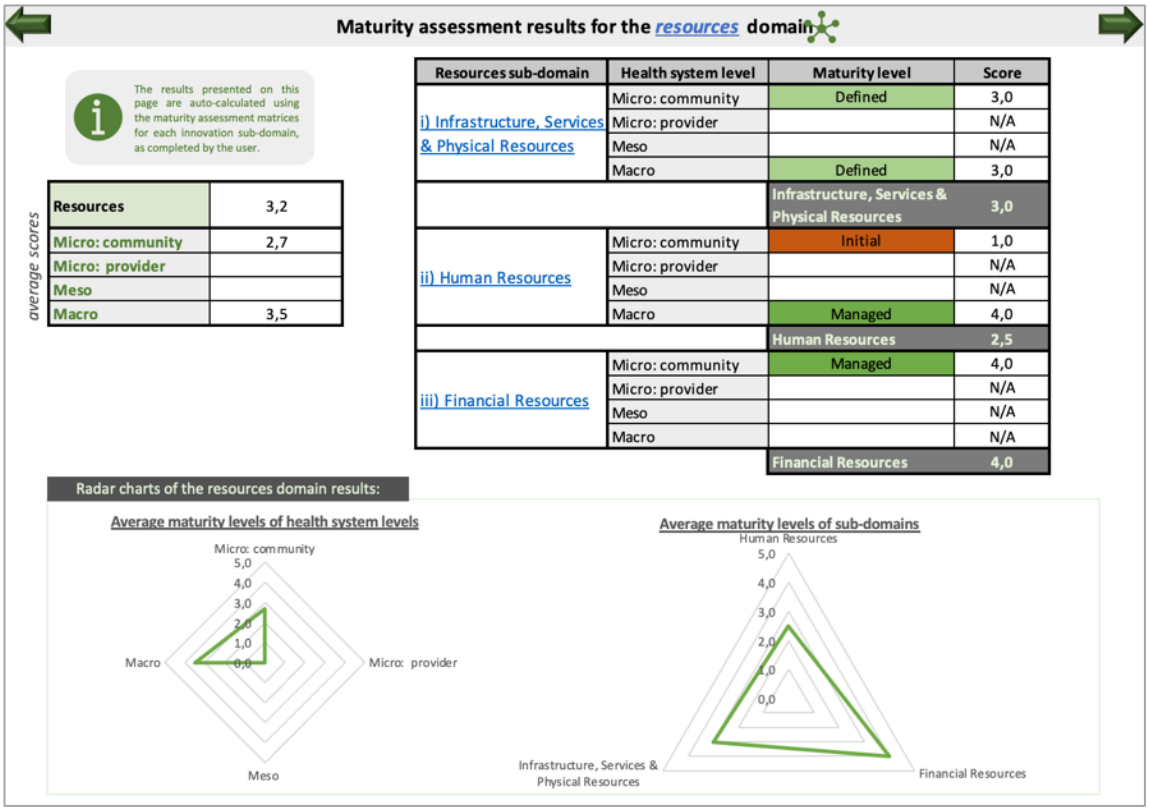

Figure 9.13: Resources domain results for the COVID Alert case study

Figure 9.13 shows that the summary maturity score for the resources domain is at level 3,2 *defined*. The resources sub-domain that achieved the lowest maturity score was human resources at 2,5, and the health system level scoring the lowest was the micro-community level at 2,7. The following sub-sections present details of the data collected for the resources domain.

ii.i) COVID Alert: Resources Maturity at Micro-Community Level

The average resources maturity score for the micro-community level is level 2,7 *defined*. Table 9.27 summarises the elements supporting the identified micro-community maturity levels for each resources sub-domain.

Table 9.27: COVID Alert summary of the resources maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Infrastructure, services & physical resources	**3**	Infrastructure, health services, and physical resources present enable the use of COVID Alert by the community. The telecommunications infrastructure in South Africa covers SU, and the university Wi-Fi further enables COVID Alert. The services that enable the use of COVID Alert are the availability of COVID-19 testing services in public and private health facilities.
Human resources	**1**	There are no apparent implementation individuals present at the community level.
Financial resources	**4**	COVID Alert was designed for the user to carry minimal operating costs; costs to the users included the data costs to download the application.

The maturity of COVID Alert's infrastructure, services & physical resources sub-domain at the micro-community level was identified as level 3. The telecommunication infrastructure available to the

community supports COVID Alert, 99,9% mobile network coverage in South Africa (The Global Economy, 2016), and SU has Wi-Fi infrastructure available to students (Stellenbosch University, 2017). The availability and high coverage of COVID-19 testing services in Western Cape, the province where SU is located, supports the operation of COVID Alert (testing sites provide unique codes to COVID-19 positive individuals to enter into COVID Alert) (Mendelson and Madhi, 2020).

COVID Alert's human resources maturity at the micro-community level was identified as level 1. There were no apparent implementation individuals present at the micro-community level. The maturity of COVID Alert's financial resources at the micro-community level was identified as level 4. Apart from the data costs to download COVID Alert, the major mobile network operators zero-rated the application so that the user does not incur additional operating costs (COVID-19 South African Online Portal, 2020).

ii.ii) COVID Alert: Resources Maturity at Macro-level

The average resources maturity score for the macro-level is level 3,5 *managed*. Table 9.28 summarises the elements supporting the identified macro-maturity levels for each resources sub-domain.

Table 9.28: COVID Alert summary of the resources maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Infrastructure, services & physical resources	**3**	Infrastructure, services & physical resources at the macro-level enable the functionality of COVID Alert. The existing COVID Connect platform and the manual contact tracing efforts were enablers.
Human resources	**4**	There were implementation individuals at the macro-level, including a coordinator and multiple champions.
Financial resources	**N/A**	There is insufficient information available to assess the macro-level financial resources sub-domain.

The maturity of COVID Alert's infrastructure, services & physical resources sub-domain at the macro-level was identified as level 4. The existing COVID Connect platform and the manual contact tracing services were enablers of COVID Alert (Modisenyane *et al.*, 2021).

The maturity of COVID Alert's human resources at the macro-level was identified as level 4. There is high-level support for COVID Alert; champions include President Cyril Ramaphosa, who encouraged people to download the application during his national statement in September 2020, and the Director General of Health (COVID-19 South African Online Portal, 2020; National Department of Health, 2020a). Furthermore, there was a coordinator at the NDOH, coordinating the application development process with Discovery Health and the launch process. Discovery Health acted as a networker; they negotiated with Google, Apple and the NDOH to enable the development of COVID Alert (Business Insider SA, 2020).

The maturity of the macro-level financial resources sub-domain was not assessed because insufficient financing information is available. Discovery Health financed the development of COVID Alert (National Department of Health, 2020a); however, there is no readily available information outlining who or how COVID Alert was maintained.

iii) COVID Alert: Institutions Domain Results

Data relevant to COVID Alert's institutions sub-domains (i) laws & regulations, (ii) policies, (iii) standards & guidelines, and (iv) institutions & priorities were analysed to determine their respective maturity levels. The COVID Alert case study results for the institutions domain are summarised in Figure 9.14.

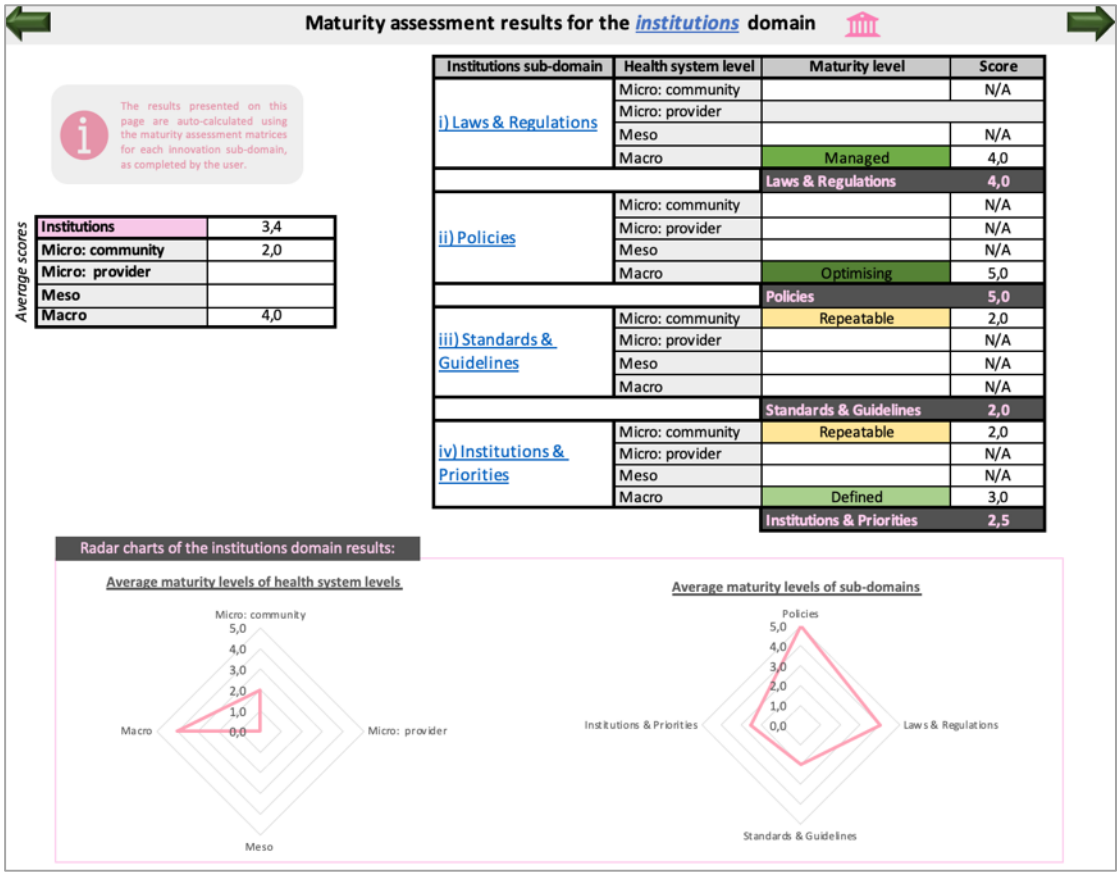

Figure 9.14: Institutions domain results for the COVID Alert case study

Figure 9.14 shows that the summary maturity score for the institutions domain is at level 3,4 *defined*. The institutions sub-domain that achieved the lowest maturity score was standards & guidelines at 2,0 and the health system level scoring the lowest was the micro-community level at 2,0, repeatable; both of these areas should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the institutions domain are presented.

iii.i) COVID Alert: Institutions Maturity at Micro-Community Level

The average institutions maturity score for the micro-community level is level 2,0 *repeatable*. Table 9.29 summarises the elements supporting the identified micro-community maturity levels for each institutions sub-domain.

Table 9.29: COVID Alert summary of the institutions maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Laws & regulations	**N/A**	Laws & regulations are not applicable to the micro-community level.
Policies	**N/A**	Policies are not applicable to the micro-community level.
Standards & guidelines	**2**	Standards & guidelines equipping community members to understand and use COVID Alert are available on COVID-19 South African Online Portal. However, awareness of this was generally lacking.
Institutions & priorities	**2**	The institutions present, namely SU, supported the general objectives of COVID Alert to prevent the spread of COVID-19; however, the actual application was not promoted – higher health was.

The maturity of standards & guidelines at the micro-community level was identified as level 2. There were no formal standards or guidelines; however, a webpage on COVID-19 South African Online Portal is dedicated to providing information and guidance on COVID Alert (National Department of Health, 2022a). There was, however, poor awareness of the COVID Alert facts at the micro-community level. The maturity of institutions & priorities at the micro-community level was identified as level 2. The primary institution present at the micro-community level is SU; the priorities of SU include health, safety and preventing the spread of COVID-19, as highlighted by SU's COVID-19 communique and campus updates (Stellenbosch University, 2020, 2021a). However, there was no official SU communique endorsing COVID Alert; SU made use of Higher Health Check[20], a symptom screening tool.

iii.ii) COVID Alert: Institutions Maturity at Macro-level

The average institutions maturity score for the macro-level is level 4,0 *managed*. Table 9.30 summarises the elements supporting the identified macro-maturity levels for each institutions sub-domain.

Table 9.30: COVID Alert summary of the institutions maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Laws & regulations	**4**	South Africa's laws & regulations do not hinder the implementation of COVID Alert.
Policies	**5**	South Africa has a very supportive policy landscape that enables the design, implementation and scaling of mHealth innovations.
Standards & guidelines	**N/A**	Standards & guidelines are not applicable at the macro-level.
Institutions & priorities	**3**	COVID Alert is closely aligned with the NDOH priorities and the international priorities outlined by the WHO.

The maturity of laws & regulations at the macro-level was identified as level 4. The regulation that guides the design and implementation of COVID Alert is the (i) National Health Act 61 of 2003, (ii) POPIA, and (iii) Disaster Management Act 57 of 2002. The maturity of policies at the macro-level was identified as level 5. As discussed in the MomConnect case study, South Africa has a supportive

[20] https://healthcheck.higherhealth.ac.za/login/?next=/

mHealth policy environment. The policies supporting COVID Alert include the: (i) 2012-2016 eHealth Strategy South Africa, (ii) 2014 National Health Normative Standards Framework for Interoperability in eHealth in South Africa, (iii) 2015-2019 mHealth strategy, and (iv) National Health Promotion Policy and Strategy.

The maturity of institutions and priorities at the macro-level was identified as level 3. COVID Alert is aligned with the NDOH priorities to contain and mitigate the spread of COVID-19 and to reduce the burden and disruptions to the health system (Pillay *et al.*, 2022). Furthermore, COVID Alert is aligned with the WHO priorities, which identify contact tracing as a crucial mechanism to contain COVID-19, and digital contact tracing solutions as tools to enhance traditional contact tracing (World Health Organization, 2020b).

iv) COVID Alert: Relations & Networks Domain Results

Data relevant to COVID Alert's relations & networks sub-domains (i) relationship dynamics, (ii) collaborations, and (iii) evaluation networks were analysed to determine their respective maturity levels. The COVID Alert case study results for the relations & networks domain are summarised in Figure 9.15.

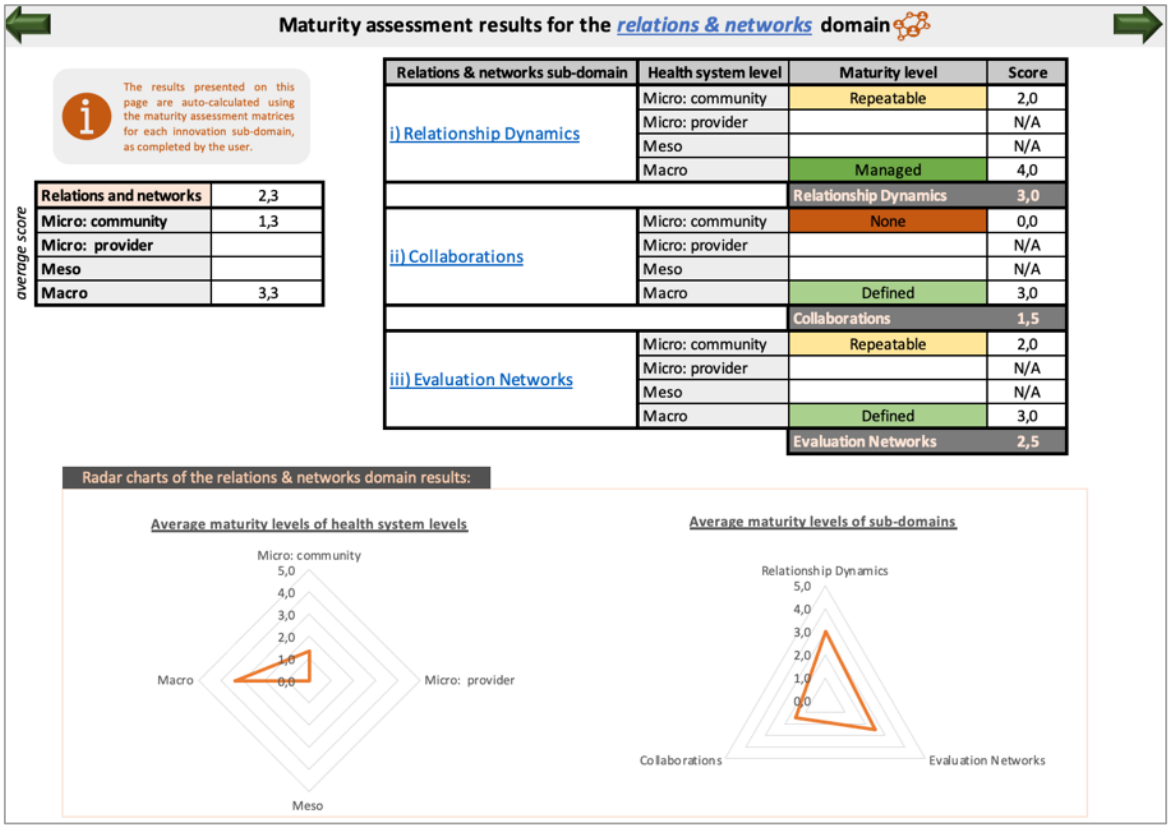

Figure 9.15: Relations & networks domain results for the COVID Alert case study

Figure 9.15 shows that the summary maturity score for the relations & networks domain is at level 2,3 *repeatable*. The relations & networks sub-domain that achieved the lowest maturity score was collaborations at 1,5, and the health system level scoring the lowest was the micro-community level at 1,3. The following sub-sections present details of the data collected for the relations & networks domain.

iv.i) COVID Alert: Relations & Networks Maturity at Micro-Community Level

The average relations & networks maturity score for the micro-community level is level 1,3 initial. Table 9.31 summarises the elements supporting the identified micro-community maturity levels for each relations & networks sub-domain.

Table 9.31: COVID Alert summary of the relations & networks maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Relationship dynamics	2	The relationship dynamics between the community and the macro-level create obstacles to adopting COVID Alert.
Collaborations	0	No clear involvement or engagement with the community.
Evaluation networks	2	There are evaluation networks through which COVID Alert users can send their feedback, namely the Google Play Store and the Apple App Store.

The maturity of relationship dynamics at the micro-community level was identified as level 2. The survey responses highlighted a general lack of trust between the community and the macro-level. One hundred ninety respondents stated their hesitancy to download COVID Alert was due to a lack of trust in the government messaging about the pandemic. Six hundred eighty-five respondents stated their hesitancy was due to COVID Alert '*probably tracking my location or storing my personal information*'.

The maturity of collaborations at the micro-community level was identified as level 0. There was no apparent involvement or engagement with the community outside of the manual contact tracing. The maturity of evaluation networks at the micro-community level was identified as level 2. The evaluation networks surrounding COVID Alert are linked to the reviews people leave after downloading the application from either the Google Play Store or the Apple App Store. These evaluation networks are not established within the NDOH; thus, the reviews by community members do not necessarily feed back to the NDOH.

iv.ii) COVID Alert: Relations & Networks Maturity at Macro-level

The macro-levels average relations & networks maturity score is level 3,3 defined. Table 9.32 summarises the elements supporting the identified macro-maturity levels for each relations & networks sub-domain.

Table 9.32: COVID Alert summary of the relations & networks maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Relationship dynamics	4	The leadership provided by the highest levels in the NDOH and the South African government enabled the implementation of COVID Alert.
Collaborations	3	Collaborations existed between the NDOH and Discovery, as well as between NDOH and the broader South African government.
Evaluation networks	3	There was an evaluation network at the macro-level, in which the uptake of COVID Alert was communicated within and subsequently by the macro-level.

The maturity of relationship dynamics at the macro-level was identified as level 4. Due to the dynamics present within high levels at which COVID Alert was endorsed, i.e., at the level of the Presidency and by the Director General of Health, COVID Alert was accepted by the macro-level.

The maturity of collaborations at the macro-level was identified as level 3. The collaborations present enabled the development and implementation of COVID Alert. The NDOH collaborated with Discovery to develop COVID Alert and with mobile network operators to zero-rate COVID Alert. The NDOH collaborated with the broader South African government, specifically with the Presidency.

The maturity of evaluation networks at the macro-level was identified as level 3. The NDOH received feedback on the uptake of COVID Alert and subsequently, on a few occasions, shared the COVID Alert uptake numbers (Business Insider SA, 2020).

v) COVID Alert: Knowledge Domain Results

Data relevant to COVID Alert's knowledge sub-domains (i) dissemination & diffusion, (ii) knowledge base & capacity, and (iii) education & training were analysed to determine their respective maturity levels. The COVID Alert case study results for the knowledge domain are summarised in Figure 9.16.

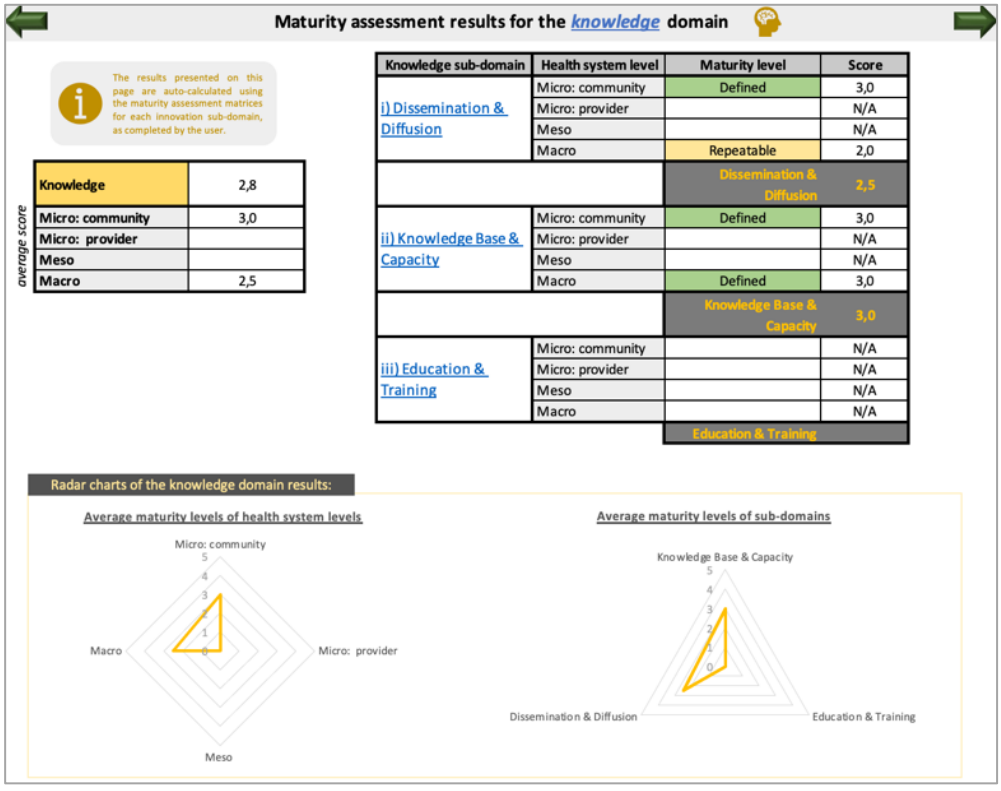

Figure 9.16: Knowledge domain results for the COVID Alert case study

As Figure 9.16 shows, the summary maturity score for the knowledge domain is at level 2,8 *repeatable*. The knowledge sub-domain that achieved the lowest maturity score is dissemination & diffusion at 2,5, and the health system level scoring the lowest was the macro-level at 2,5. The following sub-sections present details of the data collected for the knowledge domain.

v.i) COVID Alert: Knowledge Maturity at Micro-Community Level

The average knowledge maturity score for the micro-community level is level 3,0 defined. Table 9.33 summarises the elements supporting the identified micro-community maturity levels for each knowledge sub-domain.

Table 9.33: COVID Alert summary of the knowledge maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Dissemination & diffusion	**3**	There is a good awareness of COVID Alert among students. The presidency address was the dissemination channel that created the most awareness of COVID Alert.
Knowledge base & capacity	**3**	There is an existing knowledge base among the majority of community members which enables the use of COVID Alert.
Education & training	**N/A**	The maturity of education & training at the micro-community level was not assessed because this sub-domain was not deemed applicable for the uptake of COVID Alert.

The maturity of dissemination & diffusion at the micro-community level was identified as level 3. There was good awareness of COVID Alert, with 78,8% of respondents aware of COVID Alert, but only 32,1% of those who were aware had downloaded COVID Alert. The dissemination channel most frequently identified (495 respondents) as having led to community members' awareness of COVID Alert was the nationally televised address by the President, Cyril Ramaphosa, during which COVID Alert was promoted (COVID-19 South African Online Portal, 2020). Social media was identified as the second most likely dissemination channel from which students found out about COVID Alert (269 respondents), followed by word of mouth (257 respondents as the third most likely dissemination channel. here was a presence of COVID-19 misinformation among a minority of students. The misinformation included that COVID-19 is a conspiracy (15 respondents) and protection from COVID-19 through religion (30 respondents).

The maturity of the knowledge base & capacity at the micro-community level was identified as level 3. The knowledge base surrounding contact tracing existed in the majority of respondents (at least 61,3% of respondents); furthermore, the skills supporting the ability for an individual to download and use COVID Alert are present in the majority of students. This was assessed by considering survey participants' applications on their phones; most respondents reported having WhatsApp (98,8%) and Google Maps (84,8%).

v.ii) COVID Alert: Knowledge Maturity at Macro-level

The average knowledge maturity score for the macro-level is level 2,5 repeatable. Table 9.34 summarises the elements supporting the identified macro-maturity levels for each knowledge sub-domain.

Table 9.34: COVID Alert summary of the knowledge maturity of MomConnect at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Dissemination & diffusion	**2**	There was good awareness of COVID Alert among macro-level personnel due to the high-level dissemination carried out during the presidency address.
Knowledge base & capacity	**3**	The knowledge base & capacity of the macro-level is established in most macro-level actors due to existing expertise.
Education & training	**N/A**	The maturity of education & training at the macro-level was not assessed because there is insufficient information accessible to assess it.

The maturity of dissemination & diffusion at the macro-level was identified as level 2. As discussed in the relations & networks domain, there was high-level support for COVID Alert; thus, dissemination within the macro-level was done through these platforms. The maturity of knowledge base & capacity at the macro-level was identified as level 3. Due to the required public health background, most macro-level individuals have an established knowledge base on contact tracing. In addition, the WHO surge team, which was deployed to South Africa in August 2020, further capacitated macro-level individuals in the NDOH on various containment and mitigation measures, including contact tracing (World Health Organization, 2020c; Moonasar *et al.*, 2022).

vi) COVID Alert: Actors Domain Results

Data relevant to COVID Alert's actors sub-domains (i) culture, (ii) motivations, and (iii) beliefs & attitudes were analysed to determine their respective maturity levels. The COVID Alert case study results for the actors domain are summarised in Figure 9.17.

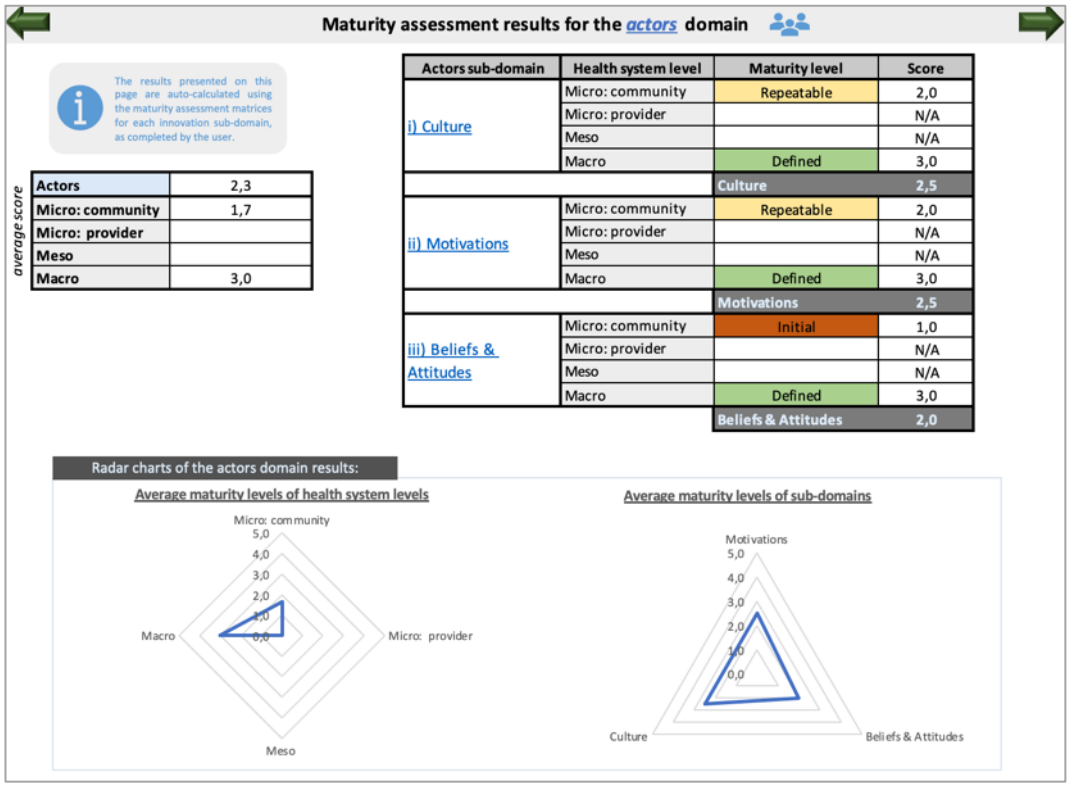

Figure 9.17: Innovation domain results for the COVID Alert case study

As Figure 9.17 shows, the actors domain's summary maturity score is at level 2,3 *repeatable*. The actors sub-domain that achieved the lowest maturity score is beliefs & attitudes at 2,0, and the health system level scoring the lowest is the micro-community level at 1,7. All of these areas should be targeted in developing improvement interventions. The following sub-sections present details of the data collected for the actors domain.

vi.i) COVID Alert: Actors Maturity at Micro-Community Level

The average actors maturity score for the micro-community level is level 1,7 initial. Table 9.35 summarises the elements supporting the identified micro-community maturity levels for each actors sub-domain.

Table 9.35: COVID Alert summary of the actors maturity at micro-community level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Culture	**2**	The student's culture does not contradict the use of COVID Alert. The existing culture of smartphone application use aligns with the innovation.
Motivations	**2**	There are a mix of incentives and disincentives present that motivate users to download/against downloading COVID Alert.
Beliefs & attitudes	**1**	Community members had negative attitudes towards COVID Alert, particularly around its perceived privacy.

The maturity of culture at the micro-community level was identified as level 2. The existing culture around phone use is an enabling factor. As the survey highlights, students have a variety of applications on their phones, ranging from applications that track a person's location (i.e., Google Maps) to social media applications (TikTok, Instagram, Facebook) that collect a person's data to develop targeted content. The maturity of motivations at the micro-community level was identified as level 2. The motivation most frequently identified was feeling a sense of responsibility (902 respondents), followed by wanting to break the chain of transmission (894 respondents), not wanting to go into a hard lockdown again (775 respondents), and wanting to complete studies in person (753 respondents). One of the mobile network operators provided an extrinsic motivation for community members to download COVID Alert by giving a 1 GB data incentive (MTN South Africa, 2021).

The maturity of beliefs & attitudes at the micro-community level was identified as level 1. There were numerous negative beliefs surrounding COVID-19 and COVID Alert, affecting attitudes. The negative belief most frequently identified by survey participants was the perceived lack of privacy when using COVID Alert; and the belief that the information provided by the government is not trustworthy.

vi.ii) COVID Alert: Actors Maturity at Macro-level

The average actors maturity score for the macro-level is level 3,0 defined. Table 9.36 summarises the elements supporting the identified macro-maturity levels for each actors sub-domain.

Table 9.36: COVID Alert summary of the actors maturity at macro-level

Sub-domain	Maturity Level	Elements Supporting the Identified Maturity Level
Culture	**3**	The organisational culture at NDOH enabled the implementation of COVID Alert.
Motivations	**3**	Incentives include the potential for COVID Alert to reduce population morbidity and mortality related to contracting COVID-19 and the burden on the health system.
Beliefs & attitudes	**3**	The macro-level attitudes were generally positive, and there were no known negative perceptions around COVID Alert.

The maturity of culture at the macro-level was identified as level 3. The NDOH has repeatedly demonstrated their ability to develop and implement mHealth interventions nationally; for example, MomConnect, NurseConnect and Health Check (Fischer *et al.*, 2019; National Department of Health, 2022b; Praekelt, 2022a). The maturity of motivations at macro-level was identified as level 3. The macro-level motivations are to prevent the loss of lives and livelihoods (Moonasar *et al.*, 2022); implementing COVID Alert is an incentive for both. COVID Alert breaks the chain of transmission while ensuring that individuals who are not infected can continue to work. The maturity of beliefs & attitudes at the macro-level was identified as level 3. The macro-level attitudes were generally positive, and there were no known negative perceptions around COVID Alert.

9.3.3.4 COVID Alert Summary Results

The summary of the results of the assessment of COVID Alert is shown in Figure 9.11. The domains with the highest scores are institutions at 3,4 – highlighting the supportive institutional environment and resources at 3,2 – highlighting that the innovation was designed to use minimal resources. The health system level with the highest score is the macro-level at 3,1 – the macro-level was the key driving force in implementing the innovation. The lowest maturity score is observed in the micro-community health system level at 2,2, which is evident from the low uptake of COVID Alert.

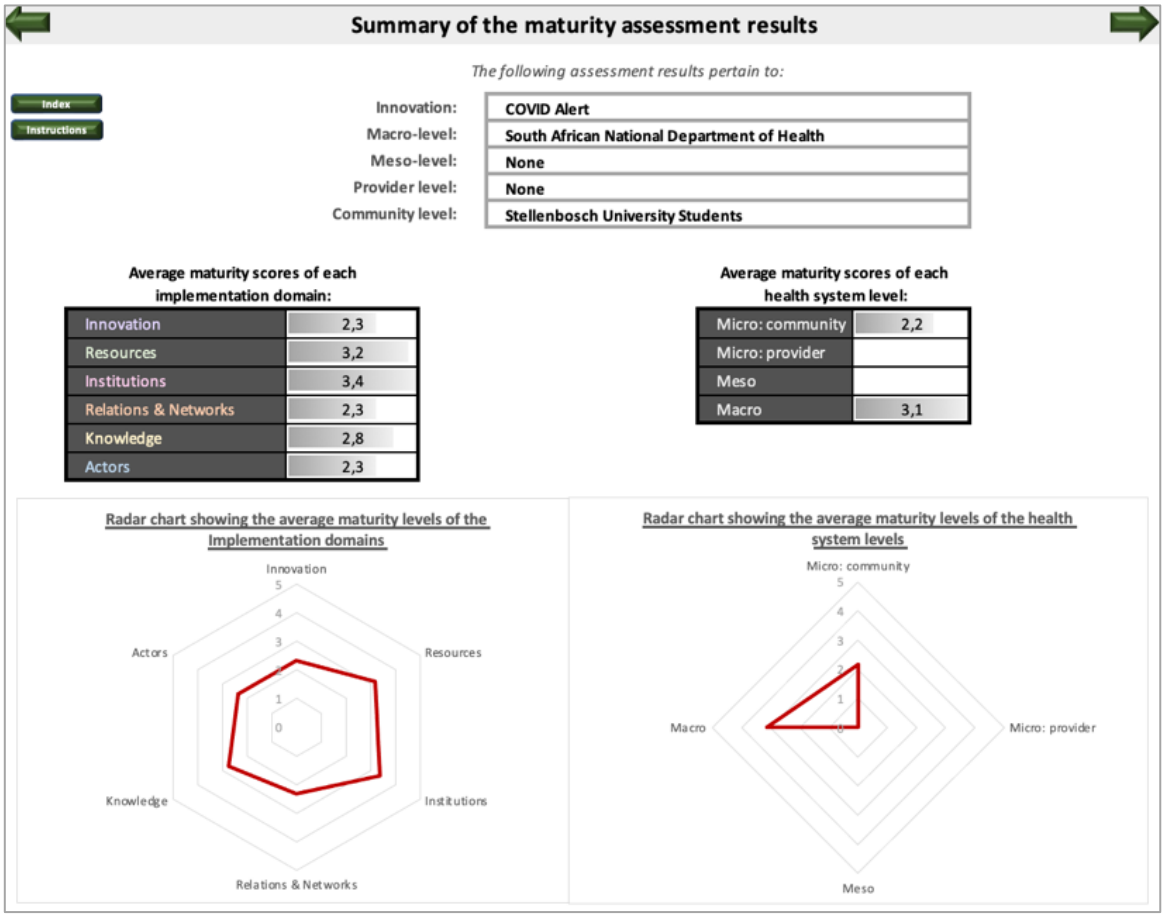

Figure 9.18: COVID Alert Summary Results

9.3.4 Key Insights from the Validation Case Studies

The validation case studies provided insights into the HII-MM's relevance, usability, and usefulness. The case studies showed the ease at which the HII-MM can be modified to assess differing health innovation landscapes. The N/A functionality effectively allows assessors to exclude health system levels and/or sub-domains that are irrelevant to an assessment scenario; this contributes to the HII-MM's flexibility. The HII-MM's flexibility is furthermore evidenced when the COVID Alert and MomConnect case studies are compared. The MomConnect innovation involves all the health system levels. In contrast, COVID Alert does not include the micro-provider or meso-level because it has been designed for use directly by the community and provided directly from the macro- to the community-level. Nevertheless, the fact that some of the HII-MM's health system levels did not apply to the COVID Alert innovation did not hinder the HII-MM's usability.

The HII-MM's usability was interrogated while the case studies were being conducted. The general considerations user interface is a useful component of the HII-MM because it makes the assessor define what should be assessed, ensuring the assessment process is well-structured. The data collection guides in the sub-domain's user interface aided the data collection process. Additionally, the two case studies showed that the HII-MM accommodates different data collection techniques. The COVID Alert case study collected data for the micro-community level primarily from a survey. In contrast, the data collected for the MomConnect case study was from academic and grey literature. The data collection guides are structured according to the maturity assessment matrices; thus,

identifying the maturity levels was relatively straightforward once the data had been collected. The visual representation of the maturity assessment results is another user-friendly aspect of the HII-MM; the visual representation allows the assessor to easily identify the aspects of the health innovation landscape acting as barriers or facilitators.

The case study results show that the HII-MM can be used to understand and identify gaps in the health innovation landscape by investigating the low maturity scores. Furthermore, the maturation paths in the HII-MM may be used to inform change and guide context-specific improvement initiatives, which is discussed further in Section 9.4.3.

9.4 REVISITING THE VALIDATION OBJECTIVES

This section establishes the extent to which the validation process fulfilled the evaluation objectives presented in Section 2.3.3 of Chapter 2. This is done by reflecting on the four validation-specific evaluation objectives: (i) validation of flexibility, (ii) validation of transferability, (iii) validation of usefulness and (iv) validation of usability.

9.4.1 Relevance: Validation of Flexibility

The SMEs were asked to critically evaluate the model's flexibility to be applied to different evidence-based health innovations, as specified in the functional requirements (refer to Section 5.1.1). The SMEs confirmed that the HII-MM provides sufficient flexibility and can be applied to the various evidence-based innovations they have experience with (refer to Table 9.1). Some SMEs remarked that with certain innovations, particularly procedural innovations, not all sub-domains or health system levels would be relevant. However, the model can still cater for this by enabling the user to exclude specific levels or sub-domains perceived as irrelevant to the innovation or context being assessed. This was demonstrated in the COVID Alert case study, where the micro-provider and meso-levels were not assessed because the community had to adopt the innovation directly. Additionally, in the MomConnect case study, particular sub-domains were not applicable at certain health system levels. For example, the financial resources sub-domain was not relevant at the meso-level. In these scenarios, the N/A feature of the HII-MM was used. In addition to the HII-MM's inherent flexibility, the N/A feature proved effective in allowing for the specifics of the respective case studies.

The two case studies practically demonstrated that the HII-MM could be applied to different evidence-based innovations. MomConnect is a mHealth innovation designed to provide expectant mothers with stage-based health information. In contrast, COVID Alert is a smartphone application designed for the general South African population to provide exposure notifications to close contacts of persons who test positive for COVID-19. he stage of the implementation process further differentiates the case studies' innovations; MomConnect was assessed at the *sustainment*[21] phase, and COVID Alert was assessed at the *inter-implementation*[22] phase. Thus, the case studies highlight the HII-MM's flexibility to be applied to different evidence-based innovations. It is validated that the model is appropriately flexible and applicable to a range of evidence-based innovations.

[21] The innovation has been implemented, continues to be successfully sustained and is integrated into the health system.
[22] The implementation of an innovation has started.

9.4.2 Relevance: Validation of Transferability

The preliminary case study, conducted in a South African setting, was used to guide the detailed description of the HII-MM during the validation interviews. This was done to enable the transferability discussions. SMEs were asked to consider the LMICs they had expertise in and to reflect on the HII-MM's transferability from South Africa to these contexts. This was done to validate that the model applies to a broad range of LMIC contexts as specified in the functional requirements (Section 5.1.1) and design restrictions (Section 5.1.3.). From their experiences, the SMEs with experience in 25 unique LMICs, agreed that the model would apply to the countries where they had expertise. Furthermore, there was a consensus that the model comprises the important aspects needed to assess implementation in an LMIC health system holistically.

The case studies were all conducted in the South African context; therefore, the case studies cannot be used to validate transferability to different countries. However, the case studies can be used to reflect on the HII-MM's transferability to different communities within a country. For the MomConnect case study, the micro-community level is pregnant women attending ANC in Gauteng public health facilities. For the COVID Alert study, the micro-community level is students attending SU. The HII-MM was able to effectively describe and assess these different population groups and their differing demographics, motivations, knowledge, etc. Therefore, the case studies show practical transferability within a country. The HII-MM is transferrable within an LMIC and to a wide range of LMIC health systems, in addition to the South African context. Thus, the HII-MM's transferability is validated.

9.4.3 Validation of Usefulness

During the validation interviews, the SMEs analysed the model to confirm whether it would be useful in practice and meet the user requirements outlined in Section 5.1.2. The SMEs agreed that the model could be useful for enlightening stakeholders and their ability to choose an innovation, understand and identify gaps, or understand what went wrong in an implementation process. Further, the SMEs agreed that the model's maturation path would be useful to inform change or guide improvement initiatives. SMEs discussed the benefits of the assessment result radar charts for benchmarking.

The case studies' results confirmed the HII-MM's ability to add value to stakeholders involved in implementing the respective health innovations. This is highlighted by the respective case study discussion and recommendations sections described in Section 9.3.2.4 for the MomConnect case study and Section 9.3.3.4 for the COVID Alert case study. The maturity assessments enabled the identification of areas for improvement for the respective case studies. They highlighted the areas where improvement initiatives should be focused, thus potentially enlightening stakeholders. The results of the MomConnect case study highlighted that improvement initiatives should be focused on the micro-provider level and the relations and networks domain. The COVID Alert case study results highlighted that the improvement initiatives should be focused on the micro-community level and on the knowledge domain.

The case studies also demonstrated the HII-MM's ability to guide improvement initiatives. The maturation paths for each health system level in a sub-domain were useful in recommending improvement initiatives. For example, in the COVID Alert case study, the recommendation to: *monitor unofficial dissemination channels (e.g., social media) for COVID-19 misinformation and*

counteract misinformation by sharing accurate information on these unofficial dissemination channels was developed from the maturation path of the dissemination & diffusion sub-domain. An example from the MomConnect study is the recommendation to *establish a feedback mechanism for health providers and ensure that regular feedback on MomConnect registrations and helpdesk responses is provided to the health providers involved with implementing MomConnect*. It was developed using the maturation path of the evaluation networks sub-domain. The SMEs validated the usefulness of the HII-MM, and the case studies corroborated its usefulness; it is concluded that the right model has been developed.

9.4.4 Validation of Usability

When contemplating the model's usability, as specified in the user requirements (refer to Section 5.1.2), the SMEs noted that they found the model user-friendly but discussed that the user would have an appropriate skill set to use it effectively. There were also discussions concerning the model's level of complexity which would likely make it time-consuming to complete an assessment. While the complexity of the model might hinder its use, this level of complexity is necessary to assess a complex dynamic system and to achieve the functional requirements (refer to Section 5.1.1).

The usability of HII-MM was reflected by using the insights from performing the validation case studies. The HII-MM was user friendly, with the hyperlinks in the HII-MM allowing for easy navigation between the different components of the model. Completing the HII-MM was a lengthy process. However, key insights from the assessment would have been missed without going into the detail that the HII-MM prompts. For example, in the MomConnect case study, the innovation's high coverage among pregnant women might have led to the assumption that there are effective dissemination & diffusion processes in place. However, further investigation of this sub-domain found that this gap could be addressed with minimal resources. There are no formalised dissemination processes meaning women are not always aware of the innovation, exacerbated by health providers not promoting MomConnect. Without the HII-MM's complexity, this insight could have been missed. The HII-MM was deemed understandable in its operationalised form; it is easily usable as a standalone tool due to the detailed instructions and explanations contained throughout the model. For all intents and purposes, the HII-MM's usability was validated.

9.5 CHAPTER 9: CONCLUSION

This chapter presents the second section of the evaluation process, and the techniques used to validate the HII-MM are described. Validation describes whether "*a measure of a concept really measures the concept it is intended to measure*" (Bryman and Bell, 2011, p.174); in the context of this study, validation is done to ensure that the HII-MM is relevant, useful and usable. The process followed to validate the HII-MM consists of validation interviews with SMEs and two case studies.

Chapter 10 Summary and Conclusions

In this chapter, the study is concluded. First, a summary of the research is presented, and the attainment of the research objectives, described in Chapter 1, is discussed. Then, the original contributions and the limitations of the research are discussed. Lastly, opportunities for future research are recommended.

Chapter 10 Outline:

10.1 RESEARCH SUMMARY

Improving the success and sustainability of innovation implementation has become one of the most apparent promoters of LMIC health system improvements. The unsuccessful and unsustainable implementation of evidence-based health innovations frequently occurs, leading to missed opportunities that could have improved various aspects of a health system. Understanding the facilitators and barriers to the implementation of innovations is especially important in the LMIC context, where unsuccessful implementation practices impede the progress and improvement of health systems. While high-income countries and LMICs experience many of the same implementation facilitators and barriers, LMICs must deal with additional health system complexities that impact implementation.

At the beginning of this study, a research gap was identified – it was noted that there was no approach that (i) applies to and enables the description of the intricacies of an LMIC context; (ii) is multi-dimensional describing and enables an understanding of a health innovation landscape; (iii) applies to a variety of evidence-based health innovations; and (iv) defines a path towards improving the success and sustainability of innovation implementation. Thus, this study was carried out to address the identified gap, resulting in the study's research product, the HII-MM.

A methodical approach was used to address the identified research gap. In Chapter 1, the need for the study was confirmed, the problem statement was defined, and the study's aim and objectives were stipulated. Thereafter, the study was delineated by defining the research scope, and the ethical considerations of the study were described. The chapter highlighted the importance of implementing healthcare innovations in LMICs and that no existing approaches sufficiently address the research gap. While the various approaches that were investigated in Chapter 1 provide valuable perspectives on implementation, they either do not (i) adequately make use of a systems thinking perspective, (ii) holistically cover the innovation system, (iii) cover the health-specific aspects that influence implementation, (iv) address the additional contextual specificities of LMICs, (v) apply to a variety of

health innovations, or (vi) define a path towards improving the success and sustainability of innovation implementation.

Once the study had been defined, a research approach was identified to guide the achievement of the study's aim and objectives; the research approach is detailed in Chapter 2. The specific research strategy followed in this study is design science. Design science was chosen as the research strategy because its properties complement the aim of this study, which is to *develop an assessment framework that improves the number of evidence-based health innovations that are successfully and sustainably implemented in LMIC contexts*. Design science can (i) describe complex systems, (ii) systematically solve a problem, and (iii) provide evidence-based solutions for real-world problems. The design science strategy allowed for sufficient flexibility to ensure the research gap (the intersection of implementation capability, health innovation systems, and LMIC context) could be addressed. The design science strategy is divided into three overarching phases: Exploratory, Formative and Evaluative Phases.

In the Exploratory Phase, three sets of exploratory literature reviews were carried out to contextualise the problem, understand its drivers and analyse potential solutions. The first literature review carried out in the Exploratory Phase is a conceptual literature review described in Chapter 3. The conceptual literature review was conducted to identify and define the fundamental concepts of a health innovation landscape that need to be understood to complete the study. The conceptual literature review aimed to investigate health systems, innovation systems and the interactions between the health and innovation system.

By integrating an innovation systems approach and a health systems view, an interdisciplinary approach is emphasised, and a greater understanding of, and a distinct perspective on the relationships that enable innovation implementation are uncovered. In the innovation system literature, the focus is on developing approaches for understanding the system; in contrast, in the health system literature, there is an emphasis on creating health system frameworks that show the system's structure. Even so, overlapping concepts exist in both literature fields, namely, functions, components, and goals. The common health and innovation system concepts identified during the conceptual review were integrated to create the Conceptual Health Innovation System framework, which includes all the concepts necessary to understand a health innovation system. The framework development process uncovered links between the often-disconnected innovation and healthcare sectors.

The second literature review carried out in the Exploratory Phase is a systematic literature review described in Chapter 4. The systematic literature review was completed to determine the facilitators and barriers to health innovation implementation in the LMIC context. The question addressed by the systematic literature review was: *What are the facilitators and barriers to implementing health innovations in LMICs?* The results from the systematic literature review were integrated with the Conceptual Health Innovation System framework developed in Chapter 3; this was done by categorising the barriers and facilitators uncovered during the review according to the Conceptual Health Innovation System framework's concepts.

The results of the systematic literature review were interpreted in the context of the broader health implementation landscape, using two commonly used health implementation frameworks, the CFIR and the i-PARIHS framework, developed in HICs. The results from the systematic literature review covered all aspects of the commonly used frameworks; however, the results place greater emphasis

on the concepts that the CFIR and i-PARIHS classified as “context” or “setting”. *Resources*, *knowledge*, *relations & networks* and *institutions* were separated from the context concept, thus allowing for them to be analysed in more detail. The lack of focus on specific contextual concepts by the CFIR and i-PARIHS is likely due to the different barriers and facilitators present in LMICs compared to HICs. This is particularly apparent in the *resources* concept, which was often cited as a significant barrier to implementation in LMICs.

The last literature review performed in the Exploratory Phase is a comparative literature review described in Chapter 5. Before describing the comparative literature review, Chapter 5 begins with defining the requirement specifications to achieve the study’s aim. The requirement specifications were developed using the results from the conceptual literature review of Chapter 3 and the results from the systematic literature review of Chapter 4. Based on the defined requirement specifications, maturity models were identified as an approach appropriate to achieve the study’s aim. Hence, a comparative literature review on existing health innovation maturity models was carried out.

The maturity models returned during the comparative literature review were assessed against the requirement specifications. While none of the maturity models identified met all the requirement specifications, they highlight that the maturity model approach is appropriate to achieve the study’s aim. Maturity models enable the description of an evolutionary improvement process and can be easily adapted to address different requirement specifications. Having confirmed that no maturity model exists, a new maturity model was developed to meet the requirement specifications during the Formative Phase.

The Formative Phase of the research strategy is described in Chapter 6, in which the solution to the identified problem was developed, namely the HII-MM. First, planning was done around the maturity model; then, the maturity model was populated using the research carried out in Chapter 2 through to Chapter 5, resulting in the preliminary maturity model. The preliminary maturity model was iteratively refined for the third step using various evaluation techniques. Once the relevant refinements had been incorporated into the preliminary maturity model, the final HII-MM was formed and presented in Chapter 6. Using the HII-MM, the as-is state of the health innovation landscape is defined, facilitating an understanding of the system’s current capability to implement a health innovation and the characteristics and properties that should be considered during an implementation process. Additionally, the HII-MM’s maturity capability statements outline an improvement roadmap or maturation path, enabling improvement initiatives’ development.

In Chapter 7, the operationalisation of the final HII-MM is presented, and its operational implications are discussed. The HII-MM is operationalised as a workbook in Microsoft Excel and comprises introductory worksheets, assessment instructions, user interfaces, and three concluding worksheets. The HII-MM enables a systems analysis of a health innovation system; therefore, its results have operational implications for the wide range of stakeholders and levels of control in the micro-community, micro-provider, meso- and macro-health system levels. Thus, the operational implications of the HII-MM are its ability to promote and improve the successful and sustainable implementation of evidence-based health innovations into LMIC health systems.

In the Evaluative Phase, there are two components: (i) verification and (ii) validation. The first component of the Evaluation Phase, verification, is described in Chapter 8. In this study, verification is done to ensure that the structure and content of the maturity model have theoretical integrity and meet the requirement specifications. The verification process described in Chapter 8 consists of two

sets of SME verification interviews and a verification case study. After each stage of the verification process, the maturity model was iteratively refined to form the HII-MM.

SMEs verified the model's content by considering the model in relation to their own experiences with innovation implementation. The SMEs agreed that the model's content applies to an LMIC context and holistically assesses an implementation process. The SMEs evaluated the model's structure to determine whether it fits its intended purpose, i.e., to assess a system's capability to implement an innovation and to define a maturation path. The SMEs were satisfied with the model's structure and did not propose any major structural refinements. In addition to the refinements resulting from the verification interviews, the practical insights gained while performing the verification case study were used to refine the maturity model further, improving the model's usability. At the end of the verification process, it was concluded that the HII-MM was theoretically and structurally verified.

The second component of the Evaluation Phase, validation, is described in Chapter 9. In the context of this study, validation is done to ensure that the HII-MM is relevant, useful, and usable. The validation process described in Chapter 9 consists of validation interviews with SMEs and two case studies. The feedback from the validation interviews and the insights gained from conducting the two case studies using the final HII-MM were used to validate the flexibility, transferability, usefulness, and usability of the HII-MM.

The SMEs confirmed that the HII-MM provides sufficient flexibility and can be applied to the various evidence-based innovations they have experience with. Some SMEs remarked that with certain innovations, particularly procedural innovations, not all sub-domains or health system levels would be relevant. However, the model can still cater for this by enabling the user to exclude specific levels or sub-domains perceived as irrelevant to the innovation or context being assessed. The two case studies practically demonstrated that the HII-MM could be applied to different evidence-based innovations.

From their experiences, the SMEs with experience in 25 unique LMICs, agreed that the model would apply to the countries where they had expertise. Furthermore, there was a consensus that the model comprises the important aspects needed to assess implementation holistically in an LMIC health system. The case studies were all conducted in the South African context; therefore, the case studies could not be used to validate transferability to different countries. However, the case studies were used to reflect on the HII-MM's transferability to different communities within a country. The HII-MM was able to effectively describe and assess these different population groups and their differing demographics, motivations, knowledge, etc. Therefore, the case studies show practical transferability within a country.

The SMEs agreed that the model could be useful for enlightening stakeholders and their ability to choose an innovation, understand and identify gaps, or understand what went wrong in an implementation process. Further, the SMEs agreed that the model's maturation path would be useful to inform change or guide improvement initiatives. SMEs discussed the benefits of the assessment result radar charts for benchmarking. The case studies' results confirmed the HII-MM's ability to add value to stakeholders involved in implementing the respective health innovations. The maturity assessments enabled the identification of areas for improvement for the respective case studies.

The case studies also demonstrated the HII-MM's ability to guide improvement initiatives. The maturation paths for each health system level in a sub-domain were useful in recommending improvement initiatives. For example, in the COVID Alert case study, the recommendation to monitor

unofficial dissemination channels (e.g., social media) for COVID-19 misinformation and counteract misinformation by sharing accurate information on these unofficial dissemination channels was developed from the maturation path of the dissemination & diffusion sub-domain.

The SMEs noted that they found the model user-friendly but discussed that the user would have an appropriate skill set to use it effectively. There were also discussions concerning the model's level of complexity, which would likely make it time-consuming to complete an assessment. While the complexity of the model might hinder its use, this level of complexity is necessary to assess a complex dynamic system.

The usability of the HII-MM was reflected by using the insights from performing the validation case studies. Completing the HII-MM was a lengthy process. However, key insights from the assessment would have been missed without going into the detail that the HII-MM prompts. For example, in the MomConnect case study, the innovation's high coverage among pregnant women might have led to the assumption that there are effective dissemination & diffusion processes in place. However, further investigation of this sub-domain found that this gap could be addressed with minimal resources. No formalised dissemination processes meant women were not always aware of the innovation, exacerbated by health providers not promoting MomConnect. Without the HII-MM's complexity, this insight could have been missed. Following the validation processes, the HII-MM was deemed usable in its operationalised form. In its operationalised form, it is usable as a standalone tool.

In Table 10.1, the research objectives defined in Chapter 1 are revisited to establish whether the study could achieve the objectives effectively. Table 10.1 describes (i) the overarching research objectives and the corresponding sub-objectives of the study, (ii) the relevant sections that addressed the respective objectives, and (iii) an evaluation of the objective achievement.

Table 10.1: Attainment of the research objectives

Sub-objective	Corresponding Section(s)	Evaluation of the Objective Achieved
RO.1 To evaluate the implementation of evidence-based innovations in LMIC health systems.		
RO.1.1 To identify facilitators and barriers to the successful and sustainable implementation of health innovations in the LMIC context	Chapter 4, Section 4.3.5	This objective is achieved by the systematic review of research papers that identify the factors (facilitators and/or barriers) influencing the successful and sustainable implementation of evidence-based health innovations in LMICs, and the subsequent extraction of these factors. The systematic literature review results are a comprehensive list of facilitators and barriers impacting health innovations' successful and sustainable implementation in the LMIC context.
RO.1.2 To evaluate the literature on health and innovation systems and to define the concepts and paradigms relevant to a generic health innovation system.	Chapter 3, Section 3.2 Section 3.3 Section 3.4	This objective is achieved in the conceptual literature review. The conceptual literature review investigates health and innovation systems individually, and the concepts specific to the respective systems are identified. Thereafter, the concepts present in the two systems are interrogated and integrated, enabling the development of a generic health innovation system, the Conceptual Health Innovation System framework. This framework includes components, functions, goals and contextual concepts that enable the description of a health innovation landscape.

Table continues on next page

Sub-objective	Corresponding Section(s)	Evaluation of the Objective Achieved
RO.2 To develop an assessment approach that enables a practical and holistic assessment of the facilitators and barriers to implementation in an LMIC health innovation system.		
RO.2.1 Using the research aim to define the requirement specifications that will ensure that the approach addresses the identified research gap.	Chapter 5, Section 5.1	The requirement specifications are defined to achieve the study's aim of developing an assessment approach that can evaluate health innovation systems and their capability to implement evidence-based innovations successfully and sustainably in LMICs. The requirement specifications are defined using the study's rationale, problem statement, research aim, objectives and scope and the results from the conceptual and systematic literature reviews. In total, 15 requirement specifications are defined and categorised into the requirement specification categories: (i) functional requirements, (ii) user requirements, (iii) boundary conditions, or (iv) design restrictions.
RO.2.2 To investigate existing health innovation maturity model approaches	Chapter 5, Section 5.2.2	A comparative literature review was carried out to understand the existing health innovation maturity model approaches. First, health maturity models were explored; thereafter, innovation maturity models were explored. Lastly, the intersection of health and innovation maturity models was investigated, and the maturity models identified in this intersection were compared to the requirement specifications.
RO.2.3 To develop an assessment approach that enables the practical and holistic assessment of the implementation process in LMIC health innovation systems.	Chapter 6 Chapter 7	This objective is achieved through the development and operationalisation of the HII-MM.
RO.3 To validate and verify the ability of the proposed approach to practically and holistically assess the facilitators and barriers to implementation present in an LMIC health innovation system.		
RO.3.1 To receive inputs from SMEs to verify the content and structure of the approach developed in RO.2.	Chapter 8 Section 8.2 Section 8.4	The HII-MM underwent a thorough verification process whereby it was iteratively refined and theoretically and structurally verified by SMEs.
RO.3.2 To receive SMEs' inputs to validate the approach's relevance, usefulness, transferability, and usability.	Chapter 9 Section 9.2	SMEs who provided inputs to validate the HII-MM have experience in a wide range of regions, namely, Sub-Saharan Africa, the Middle East & North Africa, East Asia & the Pacific, Latin America & the Caribbean, and South Asia. This experience enabled the validation of the HII-MMs transferability. The SMEs have expertise in (i) innovations, (ii) maturity models, (iii) health systems, (iv) technology systems, (v) healthcare, (vi) health innovations, and (vii) health implementation processes. This expertise enabled the validation of the HII-MM's flexibility and usability.
RO.3.3 To apply the model to several cases to further validate the approach's usability, usefulness, and flexibility.	Chapter 8 Section 8.3 Chapter 9 Section 9.3	The HII-MM was applied to one case study in its preliminary form and two case studies in its final form. The case studies were performed on different innovations in the South African setting, validating the HII-MM's flexibility. The process of performing the case studies validated the HII-MM's usability. The case study-specific recommendations validated the usefulness of the HII-MM in defining a path towards improving the success and sustainability of the innovation.

Table 10.1 highlights the methodical approach used to address the identified research gap, successfully attaining all the research objectives. Chapter 3 and Chapter 4 achieved RO.1 by providing the theory necessary to evaluate the implementation of evidence-based innovations in LMIC health systems. Chapter 5, Chapter 6 and Chapter 7 achieved RO.2 by enabling the development of an assessment approach that enables a practical and holistic assessment of the facilitators and barriers to implementation present in an LMIC health innovation system. Chapter 8 and Chapter 9 achieved RO.3 by validating and verifying the HII-MM's ability to practically and holistically assess the facilitators and barriers to implementation in an LMIC health innovation system.

10.2 CONTRIBUTIONS

The primary contribution of this study is the HII-MM presented in Chapter 6 and operationalised in Chapter 7. The HII-MM is a maturity assessment tool that facilitates a structured and systematic assessment of an LMIC health innovation landscape. It enables stakeholders to identify potential barriers and facilitators, providing them with insights into an enabling innovation implementation environment. Additionally, the HII-MM defines the system's current implementation maturity and provides an evolutionary path that can be followed to improve implementation success and sustainability.

The contribution made by the HII-MM goes beyond the consolidation of theoretical evidence of the factors that influence implementation. The HII-MM goes further by combining the theoretical evidence with a holistic health innovation landscape perspective and by including a maturation path that guides a user towards successful and sustainable implementation. Furthermore, the HII-MM includes practical insights from SMEs with real-world experiences implementing health innovations in LMICs.

The HII-MM addresses the apparent gap that no existing approach can effectively assess implementation in an LMIC health innovation landscape. This gap is evidenced in the literature reviews performed in (i) Chapter 1, in which existing implementation approaches are reviewed, (ii) Chapter 4, in which the barriers and facilitators to implementing health innovations in LMICs are systematically reviewed, and (iii) Chapter 5, in which existing health and innovation maturity models are reviewed. The novelty of the HII-MM was further corroborated by the 27 SMEs who participated in the evaluation process (refer to Section 9.2.3.4 for the discussion on the HII-MM's uniqueness).

Its use cases cover the practical contributions of the HII-MM; the HII-MM enables stakeholders to:

i. Identify and understand the factors that should be considered to support and facilitate the successful and sustainable implementation of the innovation;
ii. Benchmark innovations against one another, enabling the identification of the most suitable innovation for the health system;
iii. Benchmark potential implementation strategies against one another to identify the most suitable strategy;
iv. Identify potential barriers to the successful and sustainable implementation of the innovation by identifying gaps in the system or the innovation;
v. Guide scale-up, develop sustainability strategies, or inform change and guide improvement initiatives of the innovation, implementation strategy, or health innovation system; and

vi. Gain an understanding of what went wrong by identifying areas for improvement in subsequent implementation processes.

The specific literature field that the HII-MM contributes to is the relatively new research field called *implementation science,* also called *implementation research.* Implementation science can be defined as the "*scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services*" (Eccles and Mittman, 2006, p.1). Implementation science is a multi-disciplinary field with roots in numerous disciplines, the earliest of which is innovation implementation research. Within implementation science, authors have identified various gaps and opportunities for further research to which the HII-MM contributes. The gaps and opportunities identified include (i) incorporating stakeholders' perspectives (Lewis *et al.*, 2015; Wensing and Grol, 2019), (ii) using a systems view (Wensing and Grol, 2019; Rapport *et al.*, 2022), (iii) improving the usability of implementation frameworks (Moullin, Dickson, Stadnick, Albers, *et al.*, 2020; Beidas *et al.*, 2022; Vroom and Massey, 2022), (iv) moving away from siloed approaches (Lewis and Dorsey, 2020), (v) incorporating LMIC specific factors (Means *et al.*, 2020), and (vi) encompassing contextual factors (Bergström *et al.*, 2015; Brownson *et al.*, 2022).

The HII-MM was developed to ensure a holistic view of the health innovation system and that the model assesses not only one silo of a health innovation system but the entire system. During the development of the HII-MM, stakeholder perspectives were included through the SME interviews; this ensured that real-world insights were incorporated into the HII-MM. Systems thinking is an important part of this HII-MM as it considers the context in which a system operates and the system itself as a complex entity of interdependent and interconnected parts (Atun and Memable, 2008), which is particularly important when assessing the LMIC context. As discussed in the research summary (Section 10.1), the HII-MM incorporated a deeper understanding of the contextual factors that influence implementation, specifically in LMIC contexts. Incorporating LMIC-specific factors is a foundational aspect of the HII-MM. Usability was central to operationalising the HII-MM; the operationalised HII-MM is easily usable as a standalone tool due to the detailed instructions and explanations contained throughout the model.

In addition to the overarching contributions of the HII-MM, this study has two additional theoretical contributions. The first is the Conceptual Health Innovation System framework, which forms the conceptual foundation for the HII-MM. The Conceptual Health Innovation System framework describes the complex interactions and relationships between health and innovation systems. Innovation system theory is not often applied to the health sector, even though it is a valuable approach that promotes a greater understanding of the processes involved in developing and implementing innovations. Thus, the Conceptual Health Innovation System framework contributes to improving the integration between health and innovation system literature by providing a method for describing a health innovation landscape. The second additional theoretical contribution is identifying and categorising LMIC-specific factors (facilitators and barriers) to implement evidence-based health innovations successfully and sustainably. This was achieved by conducting a systematic literature review; the review contributes to the literature base that aims to inform health system stakeholders in LMIC on effectively and sustainably implementing evidence-based health innovations.

10.3 LIMITATIONS

There are three key limitations of this study. The first key limitation concerns the validation process, specifically the validation case studies. The case studies performed to validate the HII-MM only covered one LMIC – South Africa. Ideally, the case studies should have covered more than one LMIC. Nevertheless, the HII-MM is applicable and transferrable to different LMICs, as confirmed during the validation interviews with SMEs who had experience in 25 unique LMICs.

The second key limitation of the study concerns the scope; the scope does not include the definition of a specific improvement process. Nevertheless, this does not negate the benefits of the HII-MM because the study's scope includes the provision of a maturation path that can be used to guide the development of improvement initiatives that improve the implementation capability of the system.

The third key study limitation concerns the functionality of the HII-MM. The HII-MM does not include domain weightings that enable the differentiation between the impact that different sub-domains or health system levels will have on implementation. While there is no specific area where users can input weightings, the HII-MM does include a discussion around the differing impacts that domains and health system levels can have on an implementation process. In the next section, the limitations of this study are reflected on to identify areas for future research.

In addition to the key limitations of the study, the study includes methodological limitations. The design science research strategy used is complex, which would make it challenging to replicate the study's results; this is particularly apparent when designing in an interdisciplinary landscape, as done in this study (Reich and Subrahmanian, 2022). Furthermore, the design science research strategy outputs a single artefact (i.e., the HII-MM) to solve the identified problem. There could be multiple other artefacts able to address the problem; however, this study only developed one. Additional methodological limitations include the search strings used in the various literature reviews performed in the study. The search strings chosen might have excluded certain papers that could have been of value to the study. The selection of the SMEs interviewed during the evaluation process covered most of the global regions but not all; this could have limited the insights gained during the interviews. Lastly, SMEs did not independently use the HII-MM to implement case studies. Thus, the HII-MM's independent usability is not known.

10.4 OPPORTUNITIES FOR FUTURE RESEARCH

The recommendations for future research are orientated towards improving the usefulness and usability of the HII-MM. The following opportunities for future research should be prioritised:

i. Investigate the feasibility of standardising improvement strategies according to maturity assessment scores;
ii. Investigate the impact and feasibility of including weightings for different domains and health system levels in the operationalised HII-MM;
iii. Investigate the incorporation of a filtering feature in the operationalised HII-MM that enables only the components applicable to a specific scenario to be assessed;
iv. Translate the HII-MM to different languages to improve its transferability to other LMICs where English is not widely spoken; and
v. Convert the operationalised HII-MM into an online tool or application to increase its reach.

The first three opportunities address the study's limitations (refer to Section 10.3). Investigating the standardisation of different improvement or implementation strategies (per the first opportunity) would contribute to addressing the research gap identified by Waltz *et al.* (2019) and Miller *et al.* (2021) in choosing implementation strategies. An investigation into weightings (per the second opportunity) would contribute to the theoretical understanding of the extent to which different domains and health system levels influence implementation in different contexts. Investigating the incorporation of filtering (per the third opportunity) could contribute to reducing the perceived complexity and time needed to complete the HII-MM.

The last two opportunities would contribute to improving the practical transferability of the HII-MM. The HII-MM has been developed to be usable in a range of LMICs; thus, translating the HII-MM into other commonly spoken languages (per the fourth opportunity) would improve its usability in different LMICs. Converting the HII-MM into an online tool or application (per the fifth opportunity) would expand its geographic reach and improve its accessibility outside the academic realm. Furthermore, having the HII-MM available online would ensure that a person using the HII-MM always has access to the latest version.

10.5 CHAPTER 10: CONCLUSION

In this study, an investigation was carried out concerning health innovation systems and their capability to implement evidence-based innovations successfully and sustainably in LMICs. The study was guided by the design science research approach and was conducted in three overarching phases, the Exploratory Phase, the Formative Phase, and the Evaluative Phase. The primary research product resulting from the study is the HII-MM. The hope is that this study will empower health innovation actors to evaluate health innovation landscapes effectively and to improve the successful and sustainable implementation of evidence-based innovations in LMICs.

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Appendices

The supplementary material supporting the study's various aspects is presented within the appendices. Appendix A presents additional information supporting the research gap identification in Chapter 1. In Appendix B, additional information on the ethical implications of the study is presented, as first introduced in Chapter 1. Appendix C includes the supporting information from the conceptual literature review of Chapter 3. In Appendix D the supplementary information supporting the systematic literature review of Chapter 4 is presented. The information supporting the comparative literature review of Chapter 5 is covered in Appendix E. In Appendix F, the preliminary maturity model is presented. The information supporting the HII-MM, developed in Chapter 6, is presented in Appendix G. Components of the operationalised HII-MM, described in Chapter 7, are presented in Appendix H. The supplementary information from the evaluation process, as described in Chapter 8 and Chapter 9, is presented in Appendix I and Appendix J. Appendix I covers the supplementary information from the evaluation interviews conducted with SMEs. Appendix J consists of supplementary information from the evaluation case studies.

Appendices Outline:

Appendix A Research Gap

The additional information supporting the research gap identification in Chapter 1 is presented in this appendix. Section A.1 lists and describes existing health implementation approaches introduced in Section 1.1.2, and Section A.2 includes the search terms used to confirm the gap in the literature discussed in Section 1.1.3.

A.1 Health Implementation Approaches

The health implementation approaches identified in the reviews conducted by Moullin *et al.* (2015) and Villalobos Dintrans *et al.* (2019) were used to identify existing health implementation approaches. Table A-1 provides a list of existing health implementation approaches.

Table A-1: List of existing health implementation approaches

	Implementation science framework	Reference
1	Promoting development and uptake of health innovations: The Nose to Tail Tool	(Gupta *et al.*, 2016)
2	I - PARIHS (Promoting Action on Research Implementation in Health Services)	(Harvey and Kitson, 2016)
3	CHANGE model (customised, holistic, analytical, network-building, grassroots, evaluatory)	(Vega, 2009)
4	The Quality Implementation Framework	(Meyers, Durlak and Wandersman, 2012)
5	Expert Recommendations for Implementing Change	(Waltz *et al.*, 2014)
6	Scaling Up Global Health Interventions	(Yamey, 2011)
7	AIDED model of scale-up	(Bradley *et al.*, 2012)
8	Conceptual Model of Evidenced-Based Practice Implementation in Public Service Sectors	(Aarons, Hurlburt and Mccue Horwitz, 2010)
9	Alberta Context Tool	(Estabrooks *et al.*, 2009)
10	Organizational readiness to change assessment	(Helfrich *et al.*, 2009)
11	Context Assessment Index	(McCormack *et al.*, 2009)
12	Research Utilisation Framework	(Kim *et al.*, 2018)
13	Integrated Sustainability Framework	(Shelton, Cooper and Stirman, 2018)
14	Exploration, Preparation, Implementation, Sustainment framework	(Moullin, Dickson, Stadnick, Edwards Becan, *et al.*, 2020)
15	Non-adoption, abandonment, scale-up, spread, and sustainability (NASSS) framework	(Greenhalgh *et al.*, 2017)
16	Equitable impact sensitive tool (EQUIST)	(Waters *et al.*, 2012) (Carrera *et al.*, 2012)
17	RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance)	(Glasgow, Vogt and Boles, 1999)
18	Theoretical Domains Framework	(Michie *et al.*, 2005)
19	Practical, Robust Implementation and Sustainability Model (PRISM)	(Feldstein and Glasgow, 2008)
20	Conceptual model of implementation phases and factors affecting implementation in public service sectors	(Aarons, Hurlburt and Mccue Horwitz, 2010)
21	Consolidated Framework of Implementation Research (CFIR)	(Damschroder *et al.*, 2009)
22	Understanding-User-Context Framework	(Jacobson, Butterill and Goering, 2003)
23	General theory of implementation	(May, 2013)
24	Contingency model of innovation adoption	(Berta *et al.*, 2005)
25	Promoting Action on Research Implementation in Health Services (PARIHS)	(Kitson, Harvey and McCormack, 1998)
26	Trinity model of evidence-based practice	(Vratny and Shriver, 2007)
27	Replicating Effective Programs Framework (REP)	(Kilbourne *et al.*, 2007)
28	Ecological Framework	(Durlak and DuPre, 2008)
29	Analytic framework: moving knowledge into action	(Best, Hiatt and Norman, 2008)
30	Determinants framework of implementation from a policy perspective	(Bullock *et al.*, 2021)
31	A model of diffusion in service organizations	(Greenhalgh *et al.*, 2004)
32	Implementation Outcomes Framework	(Proctor *et al.*, 2011)
33	conceptual framework for assessing implementation costs	(Sohn *et al.*, 2020)
34	Conceptual framework for sustainability of public health programs	(Scheirer and Dearing, 2011)
35	Sustainability planning model	(Johnson *et al.*, 2004)
36	The Interactive Systems Framework for Dissemination and Implementation	(Wandersman *et al.*, 2008)
37	A stage-based approach to program change	(Simpson and Flynn, 2007)

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	Implementation science framework	Reference
38	Advancing Research and Clinical Practice Through Close Collaboration model	(Melnyk *et al.*, 2011)
39	A Framework for Building Evidence on Dissemination and Implementation in Health Services Research	(Mendel *et al.*, 2008)
40	The ARC Organizational and Community Intervention Strategy	(Glisson and Schoenwald, 2005)
41	A Theory on Sustaining and Replicating Worthwhile Innovations	(Racine, 2006)

The approaches listed in Table A-1 were screened according to exclusion criteria, to identify approaches that should be considered in more detail. The exclusion criteria are:

i. The approach does not include the phase in which the innovation is in use;
ii. The approach was developed for a specific innovation and is not generalisable;
iii. The approach does not consider the key components of a health innovation system; or
iv. The full paper in which the approach is presented is not accessible.

After applying the exclusion criteria nine approaches remained. Each of the remaining studies is described in Table A-2.

Table A-2: Health implementation approaches

Approach	Description	Reference
Practical, Robust Implementation and Sustainability Model (PRISM)	PRISM was developed to improve research translated into practice (Feldstein and Glasgow, 2008). PRISM evaluates the recipient's interaction with the healthcare innovation to establish how successful the implementation process will be (Feldstein and Glasgow, 2008). PRISM consists of four components: (i) the intervention (or innovation), (ii) recipients, (iii) the external environment, and (iv) implementation and sustainability infrastructure (Feldstein and Glasgow, 2008).	(Feldstein and Glasgow, 2008)
Conceptual model of implementation phases and factors affecting implementation in public service sectors	Aarons, Hurlburt and Mccue Horwitz (2010) develop a multi-level model to assess the implementation process. The levels of the model are (i) exploration, (ii) preparation, (iii) implementation, and (iv) sustainment; within each level, some factors have been identified as influencing the implementation process in the inner and outer context (Aarons, Hurlburt and Mccue Horwitz, 2010).	(Aarons, Hurlburt and Mccue Horwitz, 2010)
Consolidated Framework of Implementation Research	The CFIR was developed by integrating fundamental concepts from existing implementation theories; the framework can be used to evaluate implementation scenarios (Damschroder et al., 2009). The CFIR consists of five concepts, each further broken down into constructs. The concepts present in the CFIR are: (i) the characteristics of the intervention, (ii) the individual's characteristics, (iii) the outer setting, (iv) the inner organisational setting, and (v) the process (Damschroder *et al.*, 2009).	(Damschroder *et al.*, 2009)
A model of diffusion in service organisations	Greenhalgh *et al.* (2004) performed a systematic literature review investigating the diffusion of innovations within health service delivery organisations. From the review, the authors developed a conceptual framework in which they consider the innovation, the diffusion or dissemination process of the innovation, the system's readiness and antecedents, the outer inter-organisational context, and the implementation process (Greenhalgh *et al.*, 2004).	(Greenhalgh *et al.*, 2004)

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Approach	Description	Reference
General theory of implementation	The general theory of implementation developed by May (2013) combines different perspectives presented in health implementation theories. The general theory of implementation consists of (i) capacity, (ii) capability, (iii) potential, and (iv) contribution (May, 2013).	(May, 2013)
Contingency model of innovation adoption	Berta *et al.* (2005) created the contingency model of innovation adoption to improve the adoption of innovations for long-term care. The model is divided into three levels, namely: (i) individual level, (ii) organisational level, and (iii) environmental level (Berta *et al.*, 2005).	(Berta *et al.*, 2005)
Replicating Effective Programs Framework (REP)	The REP framework was developed to prepare innovations for implementation in communities (Kilbourne *et al.*, 2007). There are four phases of the REP framework, namely: (i) pre-conditions, which includes identifying a need, (ii) pre-implementation, which includes user inputs, (iii) implementation, which includes execution of the innovation, and (iv) maintenance and evolution (Kilbourne *et al.*, 2007).	(Kilbourne *et al.*, 2007)
Integrated Promoting Action on Research Implementation in Health Services (i-PARIHS)	The i-PARIHS framework is an extension of the PARIHS framework, which was initially published in 1998 (Harvey and Kitson, 2016). The PARIHS framework was one of the earliest to emphasise the importance of context and to definitively describe the complex and multi-dimensional aspects of implementation (Harvey and Kitson, 2016). The i-PARIHS framework was developed to reflect the new research in implementation science. It consists of four core concepts: (i) innovation, (ii) recipients, (iii) context, and (iv) facilitation (Harvey and Kitson, 2016).	(Harvey and Kitson, 2016)
Integrated Sustainability Framework	In the integrated sustainability framework, Shelton, Cooper and Stirman (2018) map out the factors that influence the sustainability of innovations implemented in health systems. The model consists of inner contextual factors, processes, characteristics of the implementers and characteristics of the innovation, all of which are influenced by one another and by the outer contextual factors to determine the sustainability of the innovation (Shelton, Cooper and Stirman, 2018).	(Shelton, Cooper and Stirman, 2018)

A.2 Search String Entered into Scopus to Confirm the Research Gap

Figure A-1 depicts the search string entered into the Scopus database to identify any existing LMIC health innovation implementation assessment approaches (see Section 1.1.3).

```
TITLE-ABS-KEY ( ( model OR assessment OR approach OR framework OR tool OR paradigm OR theor* ) AND ( ( ( health OR healthcare ) AND ( innovation OR {evidence-based practice} OR {evidence-based intervention} OR {evidence-based practices} OR {evidence-based interventions} ) AND ( adopt* OR implement* OR diffus* OR disseminat* OR uptake OR translat* OR appl* OR assimilat* ) ) ) AND ( ( capability OR maturity OR dimension OR factor OR barrier OR facilitator OR readiness OR challenge OR driver OR enabler OR determinant OR model OR tool OR framework OR feature OR ability OR preparedness ) ) AND ( ( low AND middle AND income OR resource AND constrained OR resource AND limited OR developing OR sub-saharan AND Africa ) OR ( angola OR benin OR botswana OR burkina AND faso OR Burundi OR Cameroon OR cape AND verde OR central AND African AND republic OR chad OR comoros OR democratic AND republic AND of AND congo OR republic AND of AND congo OR cote AND d'ivoire OR equatorial AND guinea OR eritrea OR ethiopia OR gabon OR gambia OR ghana OR guinea OR guinea-bissau OR kenya OR liberia OR madagascar OR malawi OR mali OR Mauritania OR mauritius OR mozambique OR namibia OR niger OR nigeria OR rwanda OR sao AND tome AND principe OR senegal OR seychelles OR sierra AND leone OR south AND Africa OR south AND sudan OR Swaziland OR tanzania OR togo OR uganda OR zambia OR zimbabwe ) ) )
```

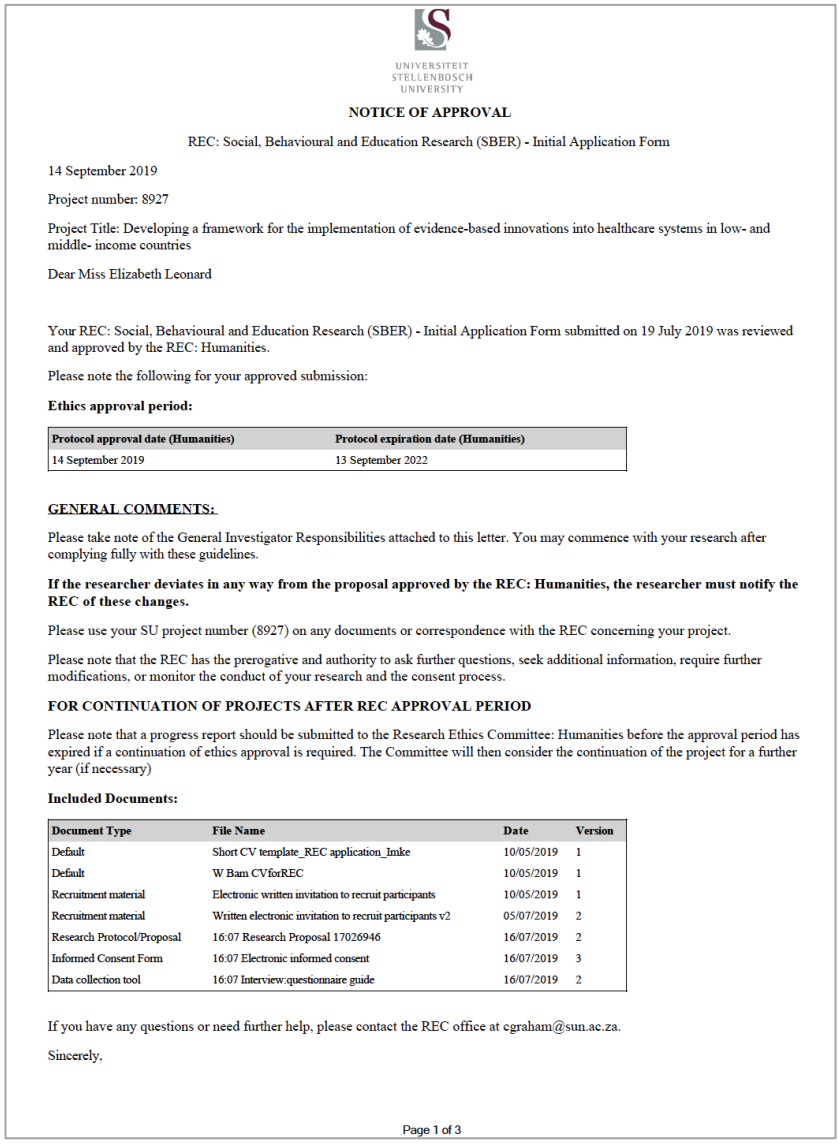
Figure A-1: Assessment approach search string

Appendix B Ethical Considerations

This appendix provides additional documentation on the ethical considerations of this study. Section B.1 presents the REC ethical approval from Stellenbosch University for the semi-structured interviews, the results of which are presented in Chapter 8 and Chapter 9, Section B.2 includes the informed consent form that was provided to potential study participants prior to an interview. Section B.3 presents the additional ethical approval necessary to conduct the COVID Alert case study, which is presented in Section 9.3.3, Chapter 9; and Section B.4 includes the informed consent form that potential survey participants had to acknowledge and accept prior to starting the COVID Alert survey.

B.1 REC Clearance for Subject Matter Expert Interviews

Figure B-1 shows the notice of approval from the REC in September 2019.



UNIVERSITEIT STELLENBOSCH UNIVERSITY

NOTICE OF APPROVAL

REC: Social, Behavioural and Education Research (SBER) - Initial Application Form

14 September 2019

Project number: 8927

Project Title: Developing a framework for the implementation of evidence-based innovations into healthcare systems in low- and middle- income countries

Dear Miss Elizabeth Leonard

Your REC: Social, Behavioural and Education Research (SBER) - Initial Application Form submitted on 19 July 2019 was reviewed and approved by the REC: Humanities.

Please note the following for your approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
14 September 2019	13 September 2022

GENERAL COMMENTS:

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number (8927) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary)

Included Documents:

Document Type	File Name	Date	Version
Default	Short CV template_REC application_Imke	10/05/2019	1
Default	W Bam CVforREC	10/05/2019	1
Recruitment material	Electronic written invitation to recruit participants	10/05/2019	1
Recruitment material	Written electronic invitation to recruit participants v2	05/07/2019	2
Research Protocol/Proposal	16:07 Research Proposal 17026946	16/07/2019	2
Informed Consent Form	16:07 Electronic informed consent	16/07/2019	3
Data collection tool	16:07 Interview questionnaire guide	16/07/2019	2

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.

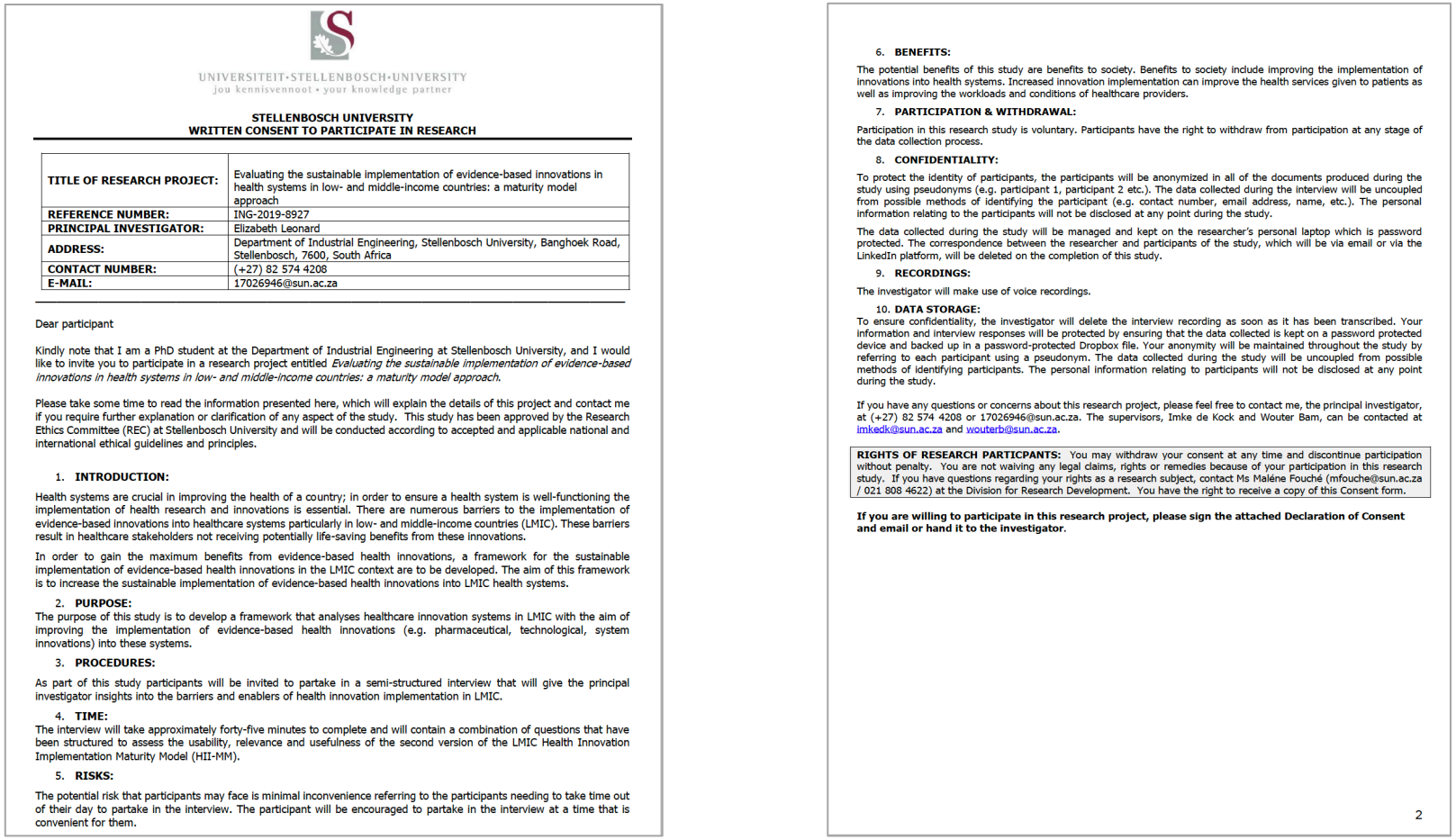
Sincerely,

Page 1 of 3

Figure B-1: Notice of ethical approval

B.2 Subject Matter Expert Interview Consent Form

Figure B-2 shows the informed consent form given to prospective participants before commencing a semi-structured interview.



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STELLENBOSCH UNIVERSITY
WRITTEN CONSENT TO PARTICIPATE IN RESEARCH

TITLE OF RESEARCH PROJECT:	Evaluating the sustainable implementation of evidence-based innovations in health systems in low- and middle-income countries: a maturity model approach
REFERENCE NUMBER:	ING-2019-8927
PRINCIPAL INVESTIGATOR:	Elizabeth Leonard
ADDRESS:	Department of Industrial Engineering, Stellenbosch University, Banghoek Road, Stellenbosch, 7600, South Africa
CONTACT NUMBER:	(+27) 82 574 4208
E-MAIL:	17026946@sun.ac.za

Dear participant

Kindly note that I am a PhD student at the Department of Industrial Engineering at Stellenbosch University, and I would like to invite you to participate in a research project entitled *Evaluating the sustainable implementation of evidence-based innovations in health systems in low- and middle-income countries: a maturity model approach*.

Please take some time to read the information presented here, which will explain the details of this project and contact me if you require further explanation or clarification of any aspect of the study. This study has been approved by the Research Ethics Committee (REC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

1. **INTRODUCTION:**

Health systems are crucial in improving the health of a country; in order to ensure a health system is well-functioning the implementation of health research and innovations is essential. There are numerous barriers to the implementation of evidence-based innovations into healthcare systems particularly in low- and middle-income countries (LMIC). These barriers result in healthcare stakeholders not receiving potentially life-saving benefits from these innovations.

In order to gain the maximum benefits from evidence-based health innovations, a framework for the sustainable implementation of evidence-based health innovations in the LMIC context are to be developed. The aim of this framework is to increase the sustainable implementation of evidence-based health innovations into LMIC health systems.

2. **PURPOSE:**

The purpose of this study is to develop a framework that analyses healthcare innovation systems in LMIC with the aim of improving the implementation of evidence-based health innovations (e.g. pharmaceutical, technological, system innovations) into these systems.

3. **PROCEDURES:**

As part of this study participants will be invited to partake in a semi-structured interview that will give the principal investigator insights into the barriers and enablers of health innovation implementation in LMIC.

4. **TIME:**

The interview will take approximately forty-five minutes to complete and will contain a combination of questions that have been structured to assess the usability, relevance and usefulness of the second version of the LMIC Health Innovation Implementation Maturity Model (HII-MM).

5. **RISKS:**

The potential risk that participants may face is minimal inconvenience referring to the participants needing to take time out of their day to partake in the interview. The participant will be encouraged to partake in the interview at a time that is convenient for them.

6. **BENEFITS:**

The potential benefits of this study are benefits to society. Benefits to society include improving the implementation of innovations into health systems. Increased innovation implementation can improve the health services given to patients as well as improving the workloads and conditions of healthcare providers.

7. **PARTICIPATION & WITHDRAWAL:**

Participation in this research study is voluntary. Participants have the right to withdraw from participation at any stage of the data collection process.

8. **CONFIDENTIALITY:**

To protect the identity of participants, the participants will be anonymized in all of the documents produced during the study using pseudonyms (e.g. participant 1, participant 2 etc.). The data collected during the interview will be uncoupled from possible methods of identifying the participant (e.g. contact number, email address, name, etc.). The personal information relating to the participants will not be disclosed at any point during the study.

The data collected during the study will be managed and kept on the researcher's personal laptop which is password protected. The correspondence between the researcher and participants of the study, which will be via email or via the LinkedIn platform, will be deleted on the completion of this study.

9. **RECORDINGS:**

The investigator will make use of voice recordings.

10. **DATA STORAGE:**

To ensure confidentiality, the investigator will delete the interview recording as soon as it has been transcribed. Your information and interview responses will be protected by ensuring that the data collected is kept on a password protected device and backed up in a password-protected Dropbox file. Your anonymity will be maintained throughout the study by referring to each participant using a pseudonym. The data collected during the study will be uncoupled from possible methods of identifying participants. The personal information relating to participants will not be disclosed at any point during the study.

If you have any questions or concerns about this research project, please feel free to contact me, the principal investigator, at (+27) 82 574 4208 or 17026946@sun.ac.za. The supervisors, Imke de Kock and Wouter Bam, can be contacted at imkedk@sun.ac.za and wouterb@sun.ac.za.

RIGHTS OF RESEARCH PARTICPANTS: You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché (mfouche@sun.ac.za / 021 808 4622) at the Division for Research Development. You have the right to receive a copy of this Consent form.

If you are willing to participate in this research project, please sign the attached Declaration of Consent and email or hand it to the investigator.

2

Figure B-2: Consent form used during interviews with subject matter experts

DECLARATION BY THE PARTICIPANT

As the **participant** I hereby declare that:

- I have read the above information and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- If the principal investigator feels that it is in my best interest, or if I do not follow the study plan as agreed to, then I may be asked to leave the study before it has finished.
- All issues related to privacy, and the confidentiality and use of the information I provide, have been explained to my satisfaction.

By signing below, I _____ agree to take part in this research study, as conducted by Elizabeth Leonard.

_____ _____

Signed at *(place)* **Date**

_____

Signature of participant

DECLARATION BY THE PRINCIPAL INVESTIGATOR

As the **principal investigator** I hereby declare that the information contained in this document has been thoroughly explained to the participant. I also declare that the participant has been encouraged (and has been given ample time) to ask any questions. In addition I would like to select the following option:

	The conversation with the participant was conducted in a language in which the participant is fluent.
	The conversation with the participant was conducted with the assistance of a translator, and this "Consent Form" is available to the participant in a language in which the participant is fluent.

_____ _____

Signed at *(place)* **Date**

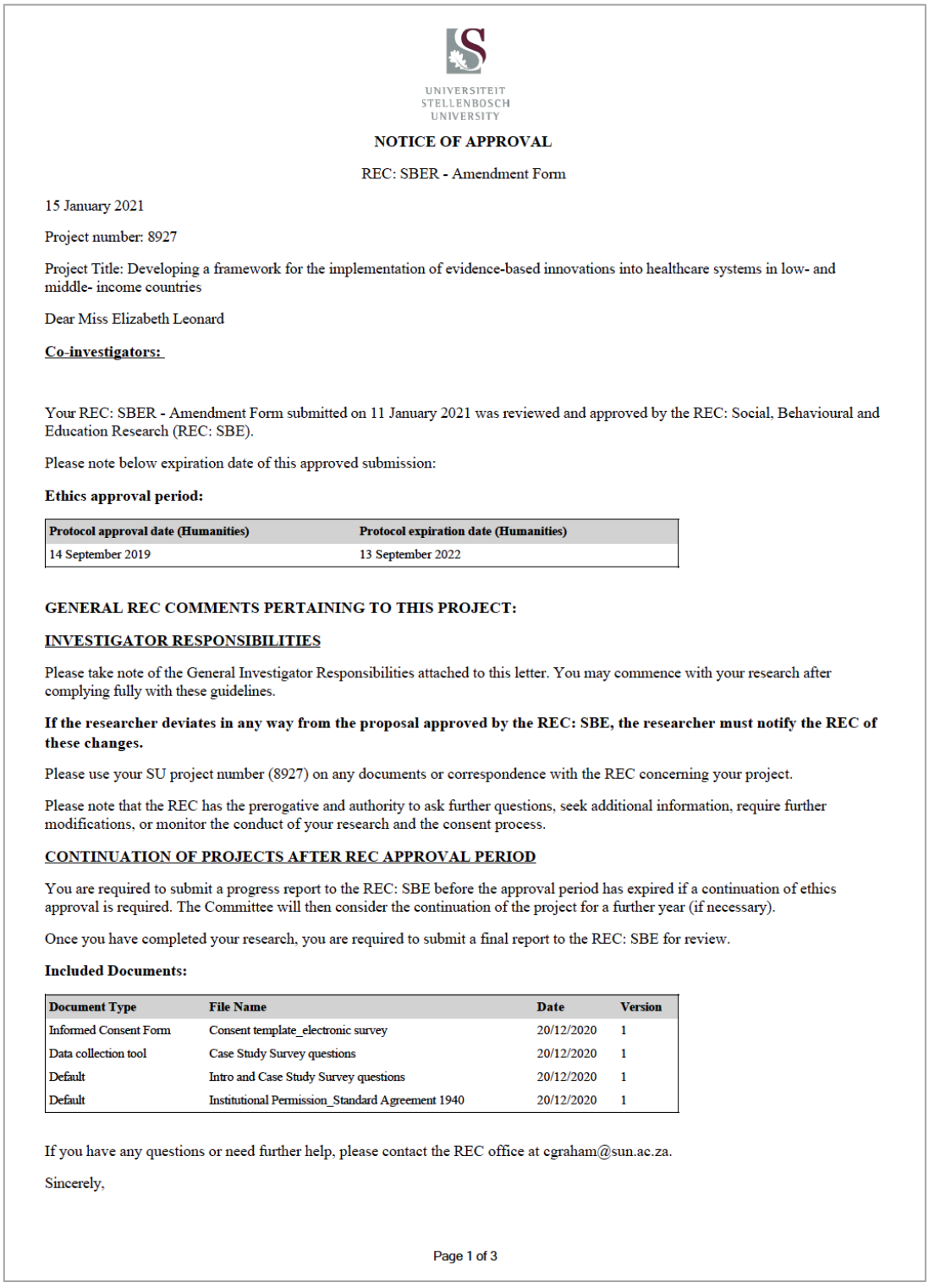
_____

Signature of Principal Investigator

Figure B-2 (cont.): Consent form used during interviews with subject matter experts

B.3 REC Clearance for COVID Alert Survey

Figure B-3 shows the notice of approval for the additional data collection technique of survey participants, which was used during the COVID Alert case study. The amended approval was obtained from the REC in January 2021.



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NOTICE OF APPROVAL

REC: SBER - Amendment Form

15 January 2021

Project number: 8927

Project Title: Developing a framework for the implementation of evidence-based innovations into healthcare systems in low- and middle- income countries

Dear Miss Elizabeth Leonard

Co-investigators:

Your REC: SBER - Amendment Form submitted on 11 January 2021 was reviewed and approved by the REC: Social, Behavioural and Education Research (REC: SBE).

Please note below expiration date of this approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
14 September 2019	13 September 2022

GENERAL REC COMMENTS PERTAINING TO THIS PROJECT:

INVESTIGATOR RESPONSIBILITIES

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: SBE, the researcher must notify the REC of these changes.

Please use your SU project number (8927) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

You are required to submit a progress report to the REC: SBE before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

Once you have completed your research, you are required to submit a final report to the REC: SBE for review.

Included Documents:

Document Type	File Name	Date	Version
Informed Consent Form	Consent template_electronic survey	20/12/2020	1
Data collection tool	Case Study Survey questions	20/12/2020	1
Default	Intro and Case Study Survey questions	20/12/2020	1
Default	Institutional Permission_Standard Agreement 1940	20/12/2020	1

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.

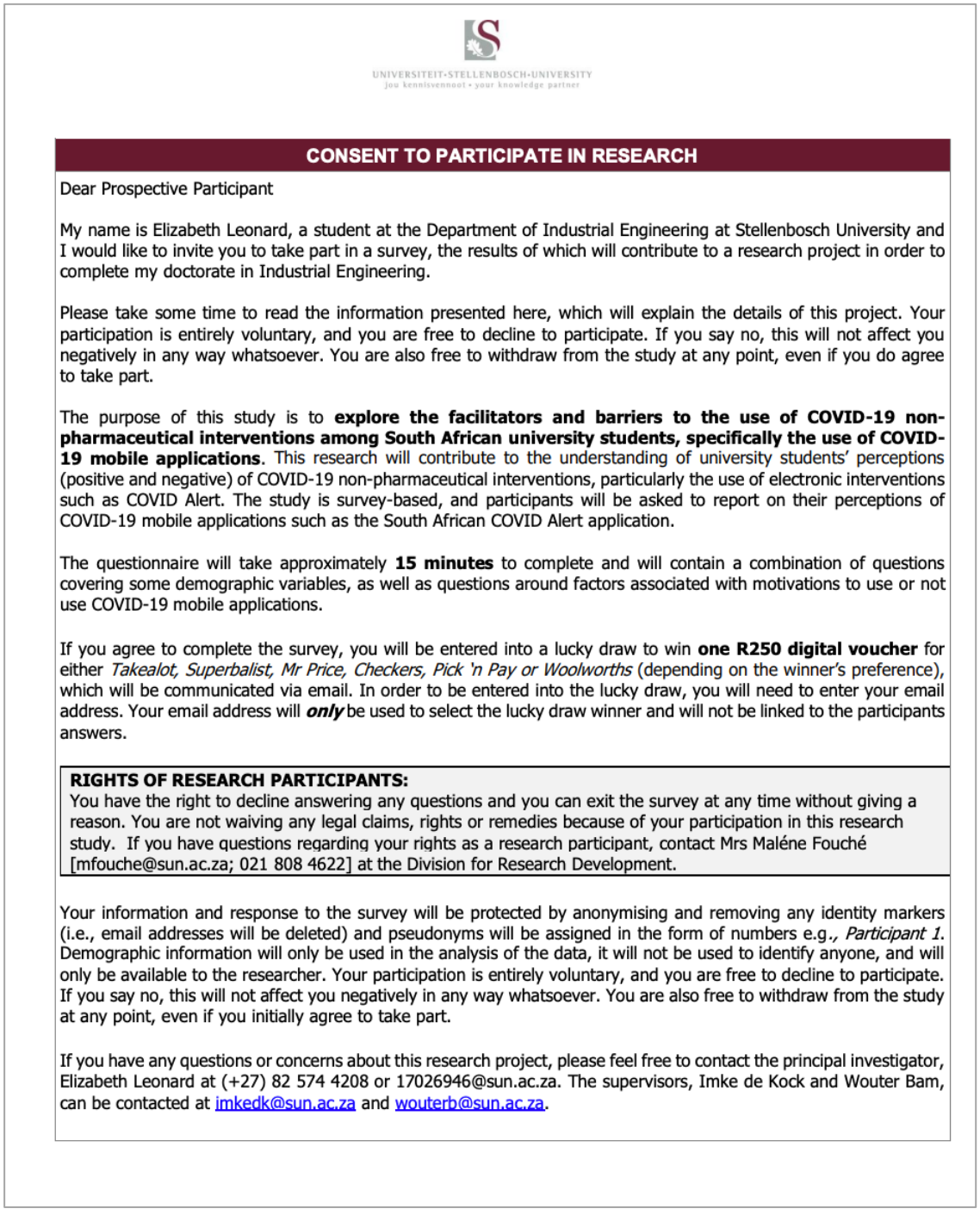
Sincerely,

Page 1 of 3

Figure B-3: Notice of additional ethical approval for the COVID Alert survey

B.4 COVID Alert Survey Consent Form

Figure B-4 shows the informed consent that prospective participants had to agree to before commencing with the electronic survey.



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CONSENT TO PARTICIPATE IN RESEARCH

Dear Prospective Participant

My name is Elizabeth Leonard, a student at the Department of Industrial Engineering at Stellenbosch University and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my doctorate in Industrial Engineering.

Please take some time to read the information presented here, which will explain the details of this project. Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

The purpose of this study is to **explore the facilitators and barriers to the use of COVID-19 non-pharmaceutical interventions among South African university students, specifically the use of COVID-19 mobile applications**. This research will contribute to the understanding of university students' perceptions (positive and negative) of COVID-19 non-pharmaceutical interventions, particularly the use of electronic interventions such as COVID Alert. The study is survey-based, and participants will be asked to report on their perceptions of COVID-19 mobile applications such as the South African COVID Alert application.

The questionnaire will take approximately **15 minutes** to complete and will contain a combination of questions covering some demographic variables, as well as questions around factors associated with motivations to use or not use COVID-19 mobile applications.

If you agree to complete the survey, you will be entered into a lucky draw to win **one R250 digital voucher** for either *Takealot, Superbalist, Mr Price, Checkers, Pick 'n Pay or Woolworths* (depending on the winner's preference), which will be communicated via email. In order to be entered into the lucky draw, you will need to enter your email address. Your email address will ***only*** be used to select the lucky draw winner and will not be linked to the participants answers.

RIGHTS OF RESEARCH PARTICIPANTS:
You have the right to decline answering any questions and you can exit the survey at any time without giving a reason. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact Mrs Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Your information and response to the survey will be protected by anonymising and removing any identity markers (i.e., email addresses will be deleted) and pseudonyms will be assigned in the form of numbers e.g., *Participant 1*. Demographic information will only be used in the analysis of the data, it will not be used to identify anyone, and will only be available to the researcher. Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you initially agree to take part.

If you have any questions or concerns about this research project, please feel free to contact the principal investigator, Elizabeth Leonard at (+27) 82 574 4208 or 17026946@sun.ac.za. The supervisors, Imke de Kock and Wouter Bam, can be contacted at imkedk@sun.ac.za and wouterb@sun.ac.za.

Figure B-4: Consent form used for the prospective survey participants

Appendix C Conceptual Literature Review Supporting Content

In this appendix, the additional supporting content for Chapter 3 is provided. Section C.1 provides the list of health system frameworks considered for the conceptual literature review. Section C.2 provides the list of health system frameworks after applying the first round of filtration criteria described in Section 3.2.2. Section C.3 describes the remaining health system frameworks after applying the second round of filtration criteria, as listed in Table 3.1 in Section 3.2.2. In Section C.4, the categorised health system elements, which were extracted from the health system frameworks, are presented. Lastly, in Section C.5, a description of the innovation system approaches presented in Section 3.3.2 is described.

C.1 Existing Health System Frameworks

Table C-1 provides a list of the health system frameworks identified during the health systems component of the conceptual literature review described in Section 3.2 of Chapter 3.

Table C-1: List of existing health system frameworks

	Health system framework	Reference
1	Actors framework	(Evans, 1983)
2	Analysing health systems to make them stronger	(Marchal *et al.*, 2010)
3	Assessing governance in developing countries' health systems	(Siddiqi *et al.*, 2008)
4	Behavioural healthcare framework	(Aday *et al.*, 1998)
5	Comparing healthcare systems with resource profiles	(Anell and Willis, 2000)
6	Component elements of health systems	(Roemer, 1993)
7	Control knobs framework	(Roberts *et al.*, 2002)
8	Converging health systems frameworks	(Shakarishvili *et al.*, 2010)
9	Core Functions framework	(British Columbia Ministry of Health Services, 2005)
10	Country level analysis of healthcare financing	(Kutzin, 2001)
11	Dimensions of health system reform	(Frenk, 1994)
12	Distributional aspects of national health insurance	(Feldstein, Friedman and Luft, 1972)
13	Econometric model of the healthcare system	(Yett *et al.*, 1972)
14	Effect of National Health Insurance on Medical Care	(Feldstein and Friedman, 1976)
15	Essential functions of public health	(Khaleghian and Das Gupta, 2005)
16	Essential Public Health Functions	(Ramagem and Ruales, 2008)
17	Framework for high performance health system in the United States	(The Commonwealth Fund, 2006)
18	Framework for monitoring and evaluating performance	(World Health Organization, 2008a)
19	Global trade and health	(Bettcher, Yach and Guindon, 2000)
20	Health policy and system performance	(Marchildon, 2014)
21	Health priority setting	(Seidman and Atun, 2016)
22	Health system framework to improve maternal, neonatal and child health (MNCH)	(Ergo *et al.*, 2011)
23	Health system functions and goals	(Musgrove *et al.*, 2000)
24	Health system governance	(Mikkelsen-Lopez, Wyss and de Savigny, 2011)
25	Health system key institutional components	(Cassels, 1995)
26	Health system performance measurement and management	(Hurst and Jee-Hughes, 2001)
27	Health system shelter	(Agyepong *et al.*, 2017)
28	Health systems and their context	(Atun and Memable, 2008)

Table continues on next page

Table continued from previous page

	Health system framework	Reference
29	Health systems in transition	(Thomson, Rechel and Ginneken, 2010)
30	Health systems strengthening framework	(Shakarishvili *et al.*, 2011)
31	Healthcare and the macro-economy	(Hsiao and Heller, 2007)
32	Healthcare expenditure and health outcomes	(Nixon and Ulmann, 2006)
33	Healthcare organisation performance framework	(Sicotte, Barnsley and Beland, 1998)
34	Healthcare system reform	(Docteur and Oxley, 2003)
35	Human resources and health outcomes	(Anand and Bärnighausen, 2004)
36	International health system performance comparison	(Veillard *et al.*, 2013)
37	Monitoring and evaluating framework of health systems strengthening	(Boerma *et al.*, 2009)
38	OECD Health Care Quality Indicators Framework	(Arah *et al.*, 2006)
39	Primary healthcare	(van Olmen *et al.*, 2010)
40	Public health grid	(Savel *et al.*, 2010)
41	Stewardship health system framework	(Veillard *et al.*, 2011)
42	Strengthening health systems	(Mills, Rasheed and Tollman, 2006)
43	Structured pluralism model of healthcare systems reform	(Londono and Frenk, 1997)
44	The Global Fund health systems strengthening	(World Health Organization, 2007b)
45	The health impact pyramid	(Frieden, 2010)
46	The World Bank: healthy development	(The World Bank, 2007)
47	WHO health performance framework	(World Health Organization, 2000)
48	WHO health system building blocks	(World Health Organization, 2007a)
49	WHO primary healthcare framework	(World Health Organization, 2008b)

C.2 Health System Frameworks Remaining After First Round of Filtering

Table C-2 provides a list of the health system frameworks remaining after a set of exclusion criteria, described in Section 3.2.2, had been applied to the frameworks listed in Table C-1. The remaining frameworks were categorised according to the categories identified in Figure 3.4, Section 3.2.2. The remaining health system framework names, categorisation and references are presented in Table C-2.

Table C-2: Health system frameworks after the first round of filtration

	Health system framework	Framework categorisation	Reference
1	Actors framework	Understanding framework	(Evans, 1983)
2	Analysing health systems to make them stronger	Informing change framework	(Marchal *et al.*, 2010)
3	Behavioural healthcare framework	Evaluating framework	(Aday *et al.*, 1998)
4	Component elements of health systems	Understanding framework	(Roemer, 1993)
5	Control knobs framework	Evaluating framework	(Roberts *et al.*, 2002)
6	Converging health systems frameworks	Understanding supra-framework	(Shakarishvili *et al.*, 2010)
7	Core Functions framework	Informing change framework	(British Columbia Ministry of Health Services, 2005)
8	Dimensions of health system reform	Informing change sub-framework	(Frenk, 1994)
9	Econometric model of the healthcare system	Understanding sub-framework	(Yett *et al.*, 1972)

Table continues on next page

Table continued from previous page

	Health system framework	Framework categorisation	Reference
10	Essential Public Health Functions	Evaluating framework	(Ramagem and Ruales, 2008)
11	Framework for monitoring and evaluating performance	Evaluating framework	(World Health Organization, 2008a)
12	Health system framework to improve maternal, neonatal and child health (MNCH)	Evaluating sub-framework	(Ergo *et al.*, 2011)
13	Health system functions and goals	Understanding framework	(Musgrove *et al.*, 2000)
14	Health system governance	Understanding framework	(Mikkelsen-Lopez, Wyss and de Savigny, 2011)
15	Health system key institutional components	Informing change supra-framework	(Cassels, 1995)
16	Health systems and their context	Understanding supra-framework	(Atun and Memable, 2008)
17	Health systems in transition	Comparing framework	(Thomson, Rechel and Ginneken, 2010)
18	Health systems strengthening framework	Evaluating framework	(Shakarishvili *et al.*, 2011)
19	OECD Health Care Quality Indicators Framework	Evaluating supra-framework	(Arah *et al.*, 2006)
20	Public health grid	Informing change sub-framework	(Savel *et al.*, 2010)
21	Stewardship health system framework	Understanding supra-framework	(Veillard *et al.*, 2011)
22	Structured pluralism model of healthcare systems reform	Informing change framework	(Londono and Frenk, 1997)
23	The Global Fund health systems strengthening	Evaluating supra-framework	(World Health Organization, 2007b)
24	WHO health performance framework	Evaluating framework	(World Health Organization, 2000)
25	WHO health system building blocks	Understanding framework	(World Health Organization, 2007a)
26	WHO primary healthcare framework	Informing change sub-framework	(World Health Organization, 2008b)

C.3 Health System Frameworks Remaining After Second Round of Filtering

The following sub-sections describe the six health system frameworks remaining after the second filtering round. These six frameworks were used to identify health system concepts (see Section 3.2).

a) Health System Building Blocks Framework

The *health system building blocks framework* (World Health Organization, 2007a) often comes up in health systems literature. Multiple authors have used it during the development of their health system frameworks. Its goal is to develop a common understanding of what a health system consists of and to identify areas where health-strengthening measures can be applied (World Health Organization, 2007a). The framework describes the six building blocks (service delivery; workforce; vaccines, products and technologies; information; governance and leadership) making up a health system (World Health Organization, 2007a). These building blocks are founded on the 2000 World Health Report, *Health Systems: Improving Performance* (World Health Organization, 2000).

Each building block is necessary to improve health outcomes (World Health Organization, 2007a). Effective service delivery entails delivering high-quality, safe services in a timeous manner with minimal waste (World Health Organization, 2007a). A health workforce should be fair, efficient and responsive, providing the highest quality of care, given its resources (World Health Organization, 2007a). Health information systems should provide accurate health information (on performance, status and factors) on time (World Health Organization, 2007a). Vaccines, technologies and other health-related products must be safe, scientifically backed, high-quality and cost-effective (World Health Organization, 2007a). Health financing systems should have a sufficient and efficient flow of funds to ensure that people can access health services without becoming impoverished (World Health Organization, 2007a). Health leadership and governance include developing alliances, regulating, ensuring accountability and system design (World Health Organization, 2007a). The framework was developed to (World Health Organization, 2007a):

i. Define a health system's desirable characteristics;
ii. Define the WHO's priorities; and
iii. Recognise where gaps in health system agendas lie.

The interdependency between the building blocks must be considered when responding to challenges and implementing improvements. Health systems are dynamic, and a change in one building block will affect other system areas (World Health Organization, 2007a).

b) Control Knobs Framework

Roberts et al. (2002) conceptualise health systems in terms of control knobs. These control knobs are a metaphor for the discrete aspects or factors that significantly influence a health system's performance (Roberts *et al.*, 2002). The framework is made up of five control knobs: (i) financing, (ii) payment, (iii) organisation, (iv) regulation and (v) behaviour. Changing the control knobs' settings (health system factors) will influence how the health system functions (Roberts *et al.*, 2002). Roberts et al. (2002) acknowledge that it is possible to conceptualise health systems in other ways; however, the benefit of this approach is that it allows for evaluating health system performance and developing solutions to performance problems.

The financing knob describes how money is raised to pay for health activities, including insurance, taxes, and direct payments (Roberts *et al.*, 2002). The payment knob describes the approaches to money transfer to the healthcare providers and the different approaches affect how healthcare providers act (Roberts *et al.*, 2002). The organisation knob refers to the techniques that can be utilised when organising the combination of healthcare providers, determining their functions and roles, how these organisations are structured and what their internal operations are (Roberts *et al.*, 2002). The regulation knob refers to the state's ability to affect the behaviour of health system actors (e.g., patients, providers, insurers) (Roberts *et al.*, 2002). The behaviour knob describes the endeavours that influence how health providers and patients act in relation to healthcare; this includes the effects of media, journals, associations, and community leaders (Roberts *et al.*, 2002).

c) Health Systems Context Framework

The *health systems context framework* provides an understanding of the connections between health systems and the environment in which such systems exist (Atun and Memable, 2008). The framework identifies three definitive health system goals: (i) health, (ii) customer satisfaction and (iii)

financial risk protection (Atun and Memable, 2008). Atun and Memable (2008) importantly include the context in which the health system exists. Factors relating to the context of the system are economic, legal and regulatory, political, demographic, technological, epidemiological and sociodemographic factors. Being able to analyse these contextual factors provides a view of the long- and short-term threats and opportunities confronted by the health system (Atun and Memable, 2008).

There are four factors that policymakers and regulators can control, which will affect the various intermediate goals and objectives (Atun and Memable, 2008). These modifiable factors include (Atun and Memable, 2008):

i. Financing: describes how health finances are collected;
ii. Organisations and regulations: refer to the policy and regulatory settings and the structures and functioning of health organisations;
iii. Resource allocation: describes how the various health resources are organised; and
iv. Provision: refers to the health services provided by the health system.

By considering the context of a particular health system, greater accuracy is possible when predicting the effects of an action on such a health system (Atun and Memable, 2008).

d) Health Systems in Transition Framework

The *health systems in transition framework* provide countries with the ability to generate detailed descriptions of their health systems in a standard setup (Thomson, Rechel and Ginneken, 2010). Health experts, in partnership with healthcare staff, can complete these frameworks. The framework consists of building blocks that can be utilised to (Thomson, Rechel and Ginneken, 2010):

i. Inspect the approaches that can be taken when considering health actors, organisations, finances and delivery;
ii. Describe the structures, processes and content for the implementation of health policies;
iii. Pinpoint challenges and sections where a more detailed analysis would be beneficial;
iv. Distribute information about health systems;
v. Promote the sharing of countries' experiences concerning health system reform;
vi. Create a point of reference for measuring the impact of health system reforms; and
vii. Communicate knowledge on comparative analysis.

In this framework, Thomson et al. (2010) provide crucial questions and definitions that enable a profile of a country's health system to be created; however, the framework does not have to be followed strictly – there is a level of flexibility.

e) Health Systems Strengthening Framework

When developing the *health systems strengthening framework,* Shakarishvili et al. (2011) considered various other health frameworks and the potential interactions between them, including (World Health Organization, 2007a) building blocks framework, Atun and Memable's (2008) health systems context framework, and Roberts et al.'s (2002) health reform framework. The *health systems strengthening framework* is built on a foundation of four components: (i) stewardship and governance, (ii) monitoring and evaluation, (iii) financing system, and (iv) health services

(Shakarishvili *et al.*, 2011). Each component consists of a combination of health system processes, elements and functions; these components are identified as the areas in which health system strengthening activities can take place (Shakarishvili *et al.*, 2011). This framework emphasises that the components are interrelated and that adjusting one part of a component will have repercussions elsewhere in the system. Each component is divided into elements, which are inputs of the components. The elements are further broken down into health system strengthening interventions, where each intervention can affect each health system element (Shakarishvili *et al.*, 2011).

f) Converging Health Systems Framework

While Shakarishvili et al. (2010) did not propose a framework in their paper, *Converging Health Systems Frameworks: Towards A Concepts-to-Actions Roadmap for Health Systems Strengthening in Low and Middle Income Countries*, they did compile elements from various health system frameworks that correspond with each other. Shakarishvili et al. (2010) propose four dimensions: goals, overarching principals, processes and building blocks; each of these dimensions comprises various components; e.g., the components within the goals dimension are better health, financial protectiveness, responsiveness and satisfaction.

C.4 Health System Framework Element Categorisation

In Table C-3, the categorised elements of each of the six frameworks, which were described in Section 3.2.2, are presented. The six frameworks were analysed and deconstructed into their basic elements and categorised according to the health system concepts (context, components, functions, goals and objectives). The concept deconstruction and categorisation process are described in Section 3.2.4.

Table C-3: Health system framework elements categorised according to the health system concepts

		Health system framework					
		Health systems building block framework (World Health Organization, 2007a)	Health systems context framework (Atun and Memable, 2008)	Control knobs framework (Roberts *et al.*, 2002)	Health systems in transition framework (Thomson, Rechel and Ginneken, 2010)	Health systems strengthening framework (Shakarishvili *et al.*, 2011)	Converging health systems frameworks (Shakarishvili *et al.*, 2010)
Health system concepts	**Context**		Economic; Political; Epidemiological; Demographic; Socio-demographic; Environmental; Technological;		Economic context; Political; Health status; Socio-demographic; Geography;		
	Components	Health workforce; Information; Medical products, vaccines, technologies; Financing; Leadership and governance;	Legal and regulatory; Financing;	Financing; Payment;	Organisation and governance; Financing; Physical resources; Human resources;	Stewardship and governance; Financing system;	Health workforce; Health information; Technologies and commodities; Financing; Governance; Payment;
	Functions	Service delivery;	Provision; Resource allocation; Organisations and regulations;	Regulation; Behaviour; Organisation;	Provision of services;	Health services; Monitoring and evaluation;	Regulation; Behaviour; Resource creation; Resource allocation; Organisation; Integration; Services; Demand generation;
	Goals and objectives	Access; Coverage; Quality; Safety; Improved health; Social and financial risk protection; Responsiveness; Improved efficiency;	Equity; Choice; Efficiency; Effectiveness; Health; Financial risk protection; Consumer satisfaction;	Access; Quality; Efficiency; Health status; Risk protection; Customer satisfaction;			Access; Coverage; Quality; Safety; Choice; Equity; Efficiency; Sustainability; Better health; Financial protection; Satisfaction; Responsiveness;

C.5 Innovation System Approaches

The following sub-sections describe the four innovation system approaches identified in Section 3.3.2. These approaches were used to identify innovation system concepts (refer to Section 3.3).

a) National Innovation System

The notion of the NIS was introduced during the 1980s (Schrempf, Kaplan and Schroeder, 2013). Three authors are predominantly associated with its development, namely, Nelson (1993), Lundvall (1992) and Freeman (1987). The NIS concept offered a new and more holistic approach to innovation in terms of how it is stimulated and governed (Schrempf, Kaplan and Schroeder, 2013). Since its conceptualisation, the NIS approach has been rapidly adopted in academia and the policy arena (Teixeira, 2014). The NIS boundaries are geographically delineated. Freeman (1987) utilised the NIS approach to explaining the innovation performance of Japan's, focusing on the interactions and feedback that occur among technological, social and economic growth (Soete, Verspagen and ter Weel, 2010). Lundvall (1992) emphasised the significance of the speed, success and extent to which innovations are produced and diffused (Soete, Verspagen and ter Weel, 2010). Nelson's (1993) approach to the NIS focuses on the actors in the system, the interactions between them, and how they are arranged.

b) Regional Innovation System

The RIS approach attempts to describe how a region's cultural and institutional environments assist or hinder the innovation process (Kaiser and Prange, 2004). The term 'regional' refers to a geographic expanse within a country; Silicon Valley is an example of a RIS in the United States of America is (Schrempf, Kaplan and Schroeder, 2013). The boundaries of the RIS approach are also geographically delineated. Compared to the NIS, the RIS approach allows the system's features to be explored in more detail, e.g., the relationships between the firms in a region (Schrempf, Kaplan and Schroeder, 2013).

c) Sectoral Innovation System

The SIS approach consists of a collection of firms involved in producing and using the technologies in a particular sector (Geels, 2004). These firms interact with one another collectively; this interaction could be cooperative or competitive (Geels, 2004). A sector consists of elements and processes that are united by a collection of products, related by demand and shared basic knowledge (Malerba, 2005). An SIS is founded on knowledge and technologies, institutions, and actors and networks (Malerba, 2005). The SIS approach uses a specific sector as the boundary of the innovation system; thus, the SIS can cross geographic boundaries and contain numerous technologies (Schrempf, Kaplan and Schroeder, 2013).

d) Technological Innovation System

Carlsson and Stankiewicz introduced the TIS approach in 1991 (Schrempf, Kaplan and Schroeder, 2013). A TIS consists of a collection of actors and guidelines that affect the pace and course of technological variations in a particular technological area (Hekkert *et al.*, 2011). The TIS uses a specific technology as the boundary of the innovation system; thus, the TIS can span multiple sectors and geographic locations (Schrempf, Kaplan and Schroeder, 2013). The TIS approach focuses on determining how the components of the TIS influence the creation, diffusion and use of specific technologies (Johnson, 2001). A significant aspect of the TIS approach relates to the system's functions (Walrave and Raven, 2016). These functions can be used diagnostically, as they can describe the innovation system at a particular time (Walrave and Raven, 2016).

Appendix D Systematic Literature Review Supporting Content

In this appendix, the additional supporting content for Chapter 4 is provided. Section D.1 presents the search strings used to complete the systematic literature and the systematic literature review search discussed in Section 4.3.2. Section D.2 presents a list of the final studies considered for the systematic literature review, the data extracted from the final studies are described in Section 4.3.5.

D.1 Search Strings Entered into Scopus for Systematic Literature Review

Figure D-1 shows search string 1, which was entered into Scopus to perform the systematic literature review of Chapter 4.

```
( TITLE-ABS-KEY (( health OR healthcare ) AND innovation AND ( adopt* OR implement* OR diffus* OR disseminat* OR uptake OR translat* OR appl* OR assimilat* ) ) ) AND ( ( capability OR maturity OR dimensions OR factors OR barrier OR facilitator OR readiness OR challenges OR drivers OR enablers OR determinants OR models OR tool OR framework OR features OR ability OR preparedness ) ) AND ( ( low AND middle AND income OR resource AND constrained OR resource AND limited OR developing OR sub-saharan AND Africa ) OR ( angola OR benin OR botswana OR burkina AND faso OR Burundi OR Cameroon OR cape AND verde OR central AND african AND republic OR chad OR comoros OR democratic AND republic AND of AND congo OR republic AND of AND congo OR cote AND d'ivoire OR equatorial AND guinea OR Eritrea OR Ethiopia OR gabon OR gambia OR ghana OR guinea OR guinea-bissau OR kenya OR liberia OR Madagascar OR Malawi OR mali OR Mauritania OR Mauritius OR Mozambique OR namibia OR niger OR nigeria OR rwanda OR sao AND tome AND principe OR senegal OR seychelles OR sierra AND leone OR south AND Africa OR south AND sudan OR Swaziland OR tanzania OR togo OR uganda OR zambia OR zimbabwe ) )
```

Figure D-1: Systematic literature review search string 1

Figure D-2 shows the additional search string, search string 2, which was entered into Scopus to perform the systematic literature review of Chapter 4.

```
( TITLE-ABS-KEY ( ( health OR healthcare ) AND ( {evidence-based practice} OR {evidence-based intervention} OR {evidence-based practices} OR {evidence-based interventions} ) AND ( adopt* OR implement* OR diffus* OR disseminat* OR uptake OR translat* OR appl* OR assimilat* ) ) ) AND ( ( capability OR maturity OR dimension OR factor OR barrier OR facilitator OR readiness OR challenge OR driver OR enabler OR determinant OR model OR tool OR framework OR feature OR ability OR preparedness ) ) AND ( ( low AND middle AND income OR resource AND constrained OR resource AND limited OR developing OR sub-saharan AND Africa ) OR ( angola OR benin OR botswana OR burkina AND faso OR Burundi OR cameroon OR cape AND verde OR central AND African AND republic OR chad OR comoros OR democratic AND republic AND of AND congo OR republic AND of AND congo OR cote AND d'ivoire OR equatorial AND guinea OR Eritrea OR Ethiopia OR gabon OR gambia OR ghana OR guinea OR guinea-bissau OR kenya OR liberia OR Madagascar OR Malawi OR mali OR Mauritania OR Mauritius OR Mozambique OR namibia OR niger OR nigeria OR rwanda OR sao AND tome AND principe OR senegal OR seychelles OR sierra AND leone OR south AND Africa OR south AND sudan OR Swaziland OR tanzania OR togo OR uganda OR zambia OR zimbabwe ) )
```

Figure D-2: Systematic literature review search string 2

D.2 Final Studies Considered in Systematic Literature Review

Table D-1 lists the final 79 studies included in the systematic literature review of Chapter 4. Table D-1 includes the reference for each study and the objectives of the selected studies.

Table D-1: Studies included in the systematic literature review

	Reference	Objective of selected study
1	(Jha *et al.*, 2016)	To develop a road map to better the implementation of kidney care in LMIC.
2	(Glasziou *et al.*, 2017)	To review knowledge on the effects and scope of medical service underuse.
3	(Hamel and Schrecker, 2011)	To understand the knowledge translation performance by health organisations in LMIC.
4	(Grover *et al.*, 2017)	To investigate the function and delivery of brachytherapy in LMIC.
5	(Aamir *et al.*, 2018)	To determine the facilitators and barriers to mHealth implementation in low-resource settings.
6	(Kiberu, Mars and Scott, 2017)	To understand the facilitators and barriers to sustainable eHealth implementation in Uganda.
7	(Peters *et al.*, 2011)	To discover conceptual frameworks for scaling up health services in developing countries.
8	(Graham and Mishra, 2011)	To investigate the implementation challenges of the human papillomavirus vaccines.
9	(Leon, Schneider and Daviaud, 2012)	To assess the challenges of mHealth scale-up in South Africa.
10	(Chopra *et al.*, 2012)	To present steps that identify and analyse the barriers that prevent health interventions from getting to the poor in LMIC.
11	(Spiegel *et al.*, 2012)	To investigate the contextual factors that impact the implementation of health information systems.
12	(Zulu *et al.*, 2014)	To identify the lessons learnt in LMIC when assimilating community-based health worker programmes into health systems.
13	(Yamey, 2012)	To determine the barriers to health intervention scale-up in LMIC.
14	(Colvin *et al.*, 2015)	To investigate the implementation process of health policy in South Africa.
15	(Wainberg *et al.*, 2017)	To investigate how LMIC are tackling the mental health implementation gap.
16	(Abejirinde *et al.*, 2018)	To identify the factors influencing the varied use of Bliss4Midwives, and to understand how to overcome these challenges.
17	(George *et al.*, 2011)	To examine the processes and policies that impact the implementation of community case management in Nicaragua.
18	(Choy *et al.*, 2013)	To investigate the barriers to implementing laparoscopic surgery in LMIC hospitals.
19	(Shields-Zeeman *et al.*, 2017)	To describe the implementation of the *Atmiyata* mental health intervention approach in India.
20	(Ishijima *et al.*, 2014)	To determine the factors that affect the implementation of quality improvement approaches in Tanzanian public hospitals.
21	(Cunningham *et al.*, 2016)	To communicate the results of a baseline study on the co-design of mHealth4Africa in Ethiopia, Kenya, Malawi and South Africa.
22	(Mijumbi-Deve and Sewankambo, 2017)	To evaluate the contextual factors that influence the implementation of a rapid response service to support decision-making in Ugandan health systems.
23	(Catalani *et al.*, 2014)	To develop a clinical decision support system that integrates HIV and TB care in Kenya.
24	(Folaranmi, 2014)	To discuss the opportunities and challenges of mHealth in Africa.
25	(Bergström *et al.*, 2015)	To develop the COACH tool for use in LMIC.
26	(Hoffman *et al.*, 2016)	To investigate the gap between knowledge practice relating to intrauterine devices and family planning in Laos, China, Mexico and Kazakhstan.
27	(Baker *et al.*, 2018)	To evaluate how health workers experienced and understood aspects of quality improvement initiatives for maternal and newborn care in Tanzania.
28	(Mbau and Gilson, 2018)	To review the impact organisational culture has on implementing health reforms in LMIC.

Table continues on next page

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	Reference	Objective of selected study
29	(Zulu *et al.*, 2015)	To explore the features that influenced the implementation of community health assistants into the Zambian health system.
30	(Fritz, Tilahun and Dugas, 2015)	To determine the criteria for the successful implementation of electronic medical records in low-resource settings.
31	(Uzochukwu *et al.*, 2016)	To describe the challenges of spanning the gap between evidence-based research and policymaking in Nigeria.
32	(Spagnolo *et al.*, 2018)	To investigate the contextual factors that influence the implementation of the Mental Health Gap Action Programme in Tunisia.
33	(Starmann *et al.*, 2018)	To investigate the factors influencing the implementation of the *SASA!* intervention in Uganda.
34	(van de Vijver *et al.*, 2015)	To develop a cardiovascular prevention model for implementation in Nairobi slums.
35	(Fowkes *et al.*, 2016)	To investigate the barriers to implementing integrated ANC in sub-Saharan Africa.
36	(Shroff *et al.*, 2017)	To study the sorts of institutional backing required to improve the creation and use of evidence in LMIC.
37	(Tran Ngoc *et al.*, 2018)	To determine the key requirements for sustainable digital health scale-up in an African context.
38	(Nwameme, Tabong and Adongo, 2018)	To investigate health workers' perspectives on the implementation of community-based health planning services in impoverished urban populations.
39	(Bazos *et al.*, 2015)	Investigating the utilisation of Microsystems Quality Improvement to improve Uganda's immunisation system.
40	(Huang, Blaschke and Lucas, 2017)	To explore the sustainable implementation of digital health interventions in Uganda and China.
41	(McRobie *et al.*, 2017)	To investigate the implementation of HIV policy in Uganda.
42	(Bloom *et al.*, 2017)	To investigate how governments and other interested parties can influence health information and communication technologies adoption in LMIC.
43	(Bardosh *et al.*, 2017)	To explore the factors impacting the implementation of the mHealth intervention, WelTel, in Kenya and Canada.
44	(Spicer *et al.*, 2018)	To identify facilitators for the implementation and scale-up of maternal and newborn health innovations in LMIC.
45	(Murray, Familiar, *et al.*, 2013)	To investigate the feasibility of implementing Trauma-Focused-Cognitive Behavioural Therapy in Zambia.
46	(Ongolo-Zogo *et al.*, 2014)	To portray the Knowledge Translation Platforms that support evidence-informed health policymaking in Uganda and Cameroon.
47	(Wilson *et al.*, 2014)	To discuss the implementation of HIV treatment as prevention.
48	(Bigna, Plottel and Koulla-Shiro, 2016)	To describe the implementation challenges of the new WHO recommendations of starting ART irrespective of the CD4 cell count.
49	(Sanner, 2017)	To investigate the longevity when implementing health information and communication technologies for development in Malawi.
50	(Bertone *et al.*, 2018)	To examine the opportunities and challenges of performance-based health financing in humanitarian settings.
51	(Bergström *et al.*, 2012)	To investigate the perceived relevance of the PARIHS framework for knowledge translation in Uganda.
52	(Ollerhead and Osrin, 2014)	To investigate the facilitators and barriers to the use of partographs during labour in LMIC.
53	(Oppong, 2015)	To investigate health innovations in income-poor environments.
54	(Vasan *et al.*, 2015)	To develop a framework to integrate primary care and surgery in LMIC.
55	(Ovbiagele, 2015)	To describe a sub-Saharan African phone-based intervention for lowering blood pressure after a stroke.
56	(L A. Palinkas *et al.*, 2015)	To examine the sustainability of HIV prevention interventions for female sex workers in Mexico.

Table continues on next page

Table continued from previous page

	Reference	Objective of selected study
57	(Murray, Shannon, *et al.*, 2013)	To investigate the implementation process of implementing evidence-based psychotherapy for children in LMIC.
58	(El-Jardali *et al.*, 2014)	To understand the activities in knowledge translation platforms that enhance evidence-based health policymaking in LMICs, and the barriers and facilitators present in these platforms.
59	(Braddick *et al.*, 2015)	To establish the facilitators and barriers to the implementation of postpartum haemorrhage guidelines in Uganda.
60	(Khatib *et al.*, 2017)	To evaluate the barriers to implementing evidence-based stroke care in LMIC.
61	(Young *et al.*, 2019)	To explore users' perspectives on implementing point-of-care testing at Kenyan antenatal facilities.
62	(Raney *et al.*, 2019)	To determine the effect of simulation training on the implementation of preeclampsia and eclampsia care in India.
63	(Shayan, Kiwanuka and Nakaye, 2019)	To evaluate the barriers to nurses implementing evidence-based practices in LMIC.
64	(Bhutta *et al.*, 2009)	To determine the factors that improve the uptake of evidence-based intrapartum and ANC.
65	(Busza *et al.*, 2012)	To analyse the facilitators and barriers to preventing mother-to-child transmission in resource-poor settings.
66	(Davy and Patrickson, 2012)	To comprehend how healthcare workers make treatment decisions in Papua New Guinea.
67	(El-Jardali *et al.*, 2012)	To understand policymakers, use of health system evidence in Eastern Mediterranean countries.
68	(Aniteye and Mayhew, 2013)	To understand the barriers to policy implementation of legal abortion in Ghana.
69	(Puchalski Ritchie *et al.*, 2016)	To investigate the implementation barriers of evidence-based maternal health products in LMIC.
70	(Alto and Petrenko, 2017)	To assess attachment-based empirically supported treatments in LMIC.
71	(Blackstone *et al.*, 2017)	To comprehend the barriers and facilitators to sustaining nurse-fronted task shifting.
72	(Tomlinson, Hunt and Rotheram-Borus, 2018)	To investigate facilitators for implementing early child development evidence-based interventions in South Africa.
73	(Nielsen *et al.*, 2018)	To evaluate the factors impacting the successful implementation of high-flow nasal cannula in Peruvia.
74	(Zepeda-Burgos, Storch and Ballabriga, 2014)	To analyse the dissemination of empirically supported treatments in El Salvador.
75	(Haines, Kuruvilla and Borchert, 2004)	To describe the effective approaches for the implementation of health research findings in low-income countries.
76	(Nzinga *et al.*, 2009)	To investigate the barriers to implementing guidelines in Kenyan hospitals.
77	(Pérez-escamilla *et al.*, 2012)	To evaluate the scale-up of breastfeeding programs in LMIC.
78	(Iwelunmor *et al.*, 2016)	To explore the sustainability of health interventions in sub-Saharan Africa.
79	(Diaconu *et al.*, 2017)	To determine the factors for the prioritisation and procurement of medical devices in LMIC.

Appendix E Comparative Review Supporting Content

This appendix presents the additional information supporting the comparative literature review of Chapter 5. Section E.1 includes the various search terms used to carry out the different sections of the comparative literature review.

E.1 Search String Entered into Scopus for Review of Maturity Models

Figure E-1 depicts the search string entered into the Scopus database to identify existing health maturity models in Section 5.2.2.1.

```
TITLE-ABS-KEY ( ( {maturity model} OR {maturity grid} OR {maturity matrix} OR {maturity assessment} OR {maturity levels} ) AND ( ( health OR healthcare )
```

Figure E-1: Health maturity model search string

Figure E-2 depicts the search string entered into the Scopus database to identify existing innovation maturity models in Section 5.2.2.2.

```
TITLE-ABS-KEY ( ( {maturity model} OR {maturity grid} OR {maturity matrix} OR {maturity assessment} OR {maturity levels} ) AND ( ( innovation OR {evidence-based practice} OR {evidence-based intervention} OR {evidence-based practices} OR {evidence-based interventions} )
```

Figure E-2: Innovation maturity model search string

Figure E-3 depicts the search string entered into the Scopus database to identify existing health innovation maturity models in Section 5.2.2.3.

```
TITLE-ABS-KEY ( ( ( ( health OR healthcare ) AND ( innovation OR {evidence-based practice} OR {evidence-based intervention} OR {evidence-based practices} OR {evidence-based interventions} ) AND ( adopt* OR implement* OR diffus* OR disseminat* OR uptake OR translat* OR appl* OR assimilat* ) ) ) AND ( ( capability OR maturity OR dimensions OR factors OR barrier OR facilitator OR readiness OR challenges OR drivers OR enablers OR determinants OR models OR tool OR framework OR features OR ability OR preparedness ) ) AND ( {maturity model} OR {maturity grid} OR {maturity matrix} OR {maturity assessment} OR {maturity levels} ) )
```

Figure E-3: Health innovation implementation maturity model search string

Appendix F Preliminary Maturity Model

In this appendix, the preliminary maturity model is presented. Section F.1 describes the first dimension of the preliminary maturity model, *health system levels*. Section F.2, describes the second dimension of the preliminary maturity model, *implementation domains*. In Section F.3, the third dimension of the maturity model, *maturity levels*, is described. Lastly, Section F.4 presents the interaction between these three dimensions in the form of the conceptual, preliminary maturity model.

F.1 Dimension 1: Health System Levels

The health system levels are described using levels of analysis; there are three different levels of analysis: (i) micro, (ii) meso, and (iii) macro (Serpa and Ferreira, 2019). The preliminary maturity model's health system levels of analysis are presented in Figure F-1 and consist of (i) macro: national, (ii) meso: sub-national, (iii) micro: health facility, and (iv) micro: community. The term sub-national was used for the meso-level because of the varying subdivisions, structures and terms used in different LMICs. The micro-health system level was split into two components: (i) health facility level and (ii) community level.

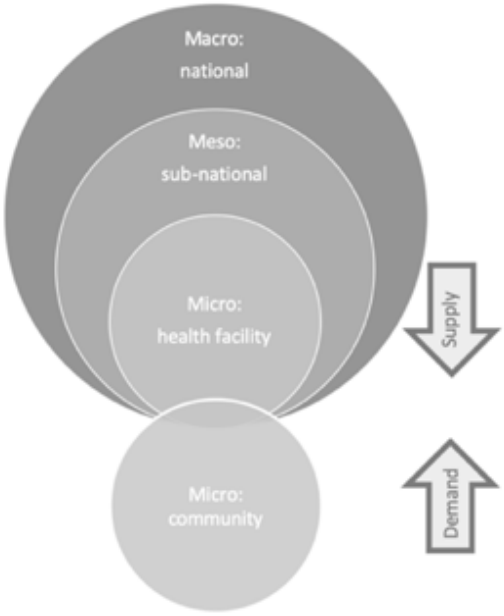

Figure F-1: Preliminary maturity model health system levels, adapted from (Bazos et al., 2015)

F.2 Dimension 2: Implementation Domains

The preliminary maturity model's overarching implementation domains are (i) innovation, (ii) institutions, (iii) knowledge, (iv) relations & networks, (v) actors, (vi) resources, and (vii) context. The implementation domains and corresponding sub-domains that were included in the preliminary maturity model are presented in Table F-1. The implementation domains provide a holistic view of the facilitators and barriers to implementing an innovation in an LMIC context.

Table F-1: Preliminary maturity model implementation domain descriptions and the corresponding sub-domains

Domain	Definition of domain	Sub-domains
Innovation	Health innovation is any new "*concept, idea, service, process, or product"* which aims to improve some aspect of health, including health education, treatments, prevention, diagnosis, outreach or research (Omachonu and Einspruch, 2010);	Interoperability & adaptability Perception Functionality Evidence strength Ethics Degree of novelty Design
Institutions	Institutions are established as widespread laws, rules or practices that shape social interactions (Hodgson, 2006); they offer structure and insights into how actors behave in the system (Soete, Verspagen and ter Weel, 2010). The roles of institutions are to guide and oversee the health system and protect the population who use and who are part of the health system (World Health Organization, 2007a).	Policies Regulatory system Political priorities Standards & guidelines
Knowledge	Knowledge is the information and understanding of a subject area (Collins English Dictionary, 2019c).	Knowledge base Capacity Education Dissemination
Relations and networks	Relations describe how things are connected; a network is a group of interconnected people or things. Health innovation networks and relations link groups of actors at the national, regional or international level (Chataway *et al.*, 2009).	Relationships & leadership Evaluation, feedback & communication Collaborations
Actors	Actors are any people who participate in health system actions or processes. The actors in the health innovation system create, diffuse and use the innovations (Hekkert *et al.*, 2011). Healthcare actors include (i) patients, (ii) providers, (iii) payers, (iv) suppliers and (v) regulators (Bessant, Kunne and Möslein, 2012).	Incentives & motivation Beliefs & attitudes Culture
Resources	The supply of something a country has and can use (Oxford Dictionaries, 2019f).	Human Financial Physical Time
Context	Context refers to the circumstances that structure the background in which the health system exists, the conditions by which the health system can be understood entirely (Oxford Dictionaries, 2019a).	Environmental Political Socio-cultural

F.3 Dimension 3: Maturity Levels

The assessment measure used in maturity models, are maturity levels. The maturity levels which were used to develop the preliminary maturity model are structured according to the CMM; the maturity levels are described in Table F-2, Level 0 represents the lowest maturity level and Level 5 represents the highest, optimal level of maturity.

Table F-2: Generic descriptions of maturity levels (CMMI Product Team, 2002)

Maturity level	Description
Level 0: none	Does not exist.
Level 1: initial	Ad-hoc or chaotic processes, any success is the result of individuals.
Level 2: repeatable	Processes are managed, measured, and controlled.
Level 3: defined	Processes are established and understood.
Level 4: managed	Processes are quantitatively managed, they are predictable.
Level 5: optimising	Focus is on optimising and continuously improving the processes.

F.4 Conceptual Preliminary Maturity Model

The three dimensions described in Sections F.1, F.2 and F.3 are integrated to develop the preliminary maturity model shown in Figure F-2. The preliminary maturity model consists of three planes resulting from the interactions between the dimensions.

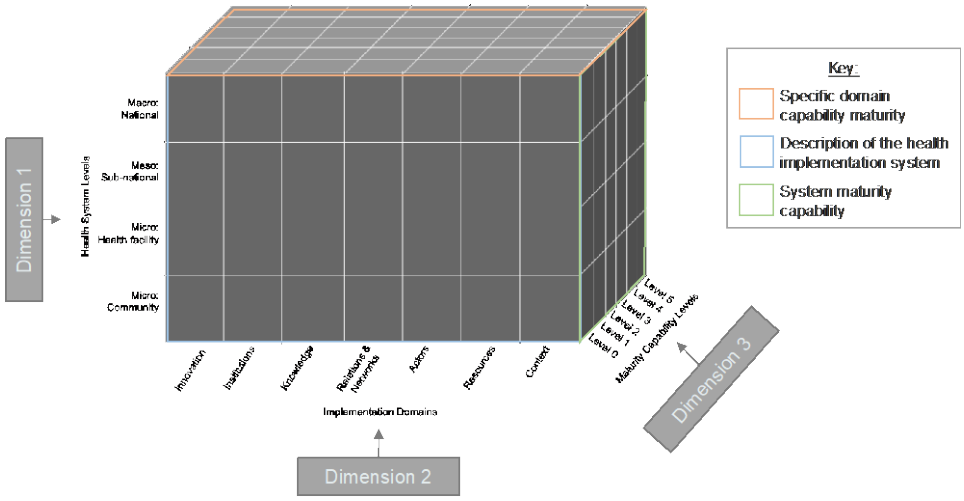

Figure F-2: Conceptual overview of the preliminary maturity model

The interactions between the dimensions are presented in Figure F-3. The amalgamation of Dimension 2: implementation domains and Dimension 1: health system levels, resulting in a *description of the health implementation system*. The amalgamation of Dimension 2: implementation domains, and Dimension 3: maturity capability levels, result in the *specific implementation domain capability maturity statements*. The generic maturity level statements of Table F-2 are individualised for each implementation domain. The *description of the health implementation system* and *the specific domain capability maturity statements* are integrated to create the *health system implementation maturity capabilities* for each implementation domain (innovation, institutions, knowledge, relations & networks, actors, resources, context).

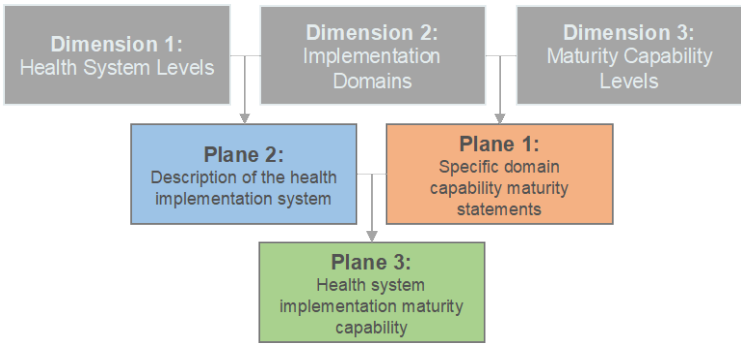

Figure F-3: Flowchart showing the interactions between the preliminary maturity model's three dimensions

Plane 3: *health system implementation maturity capability* consists of the maturity model user interfaces. Figure F-4 outlines the components of a user interface in the preliminary maturity model; each implementation sub-domain has a user interface for.

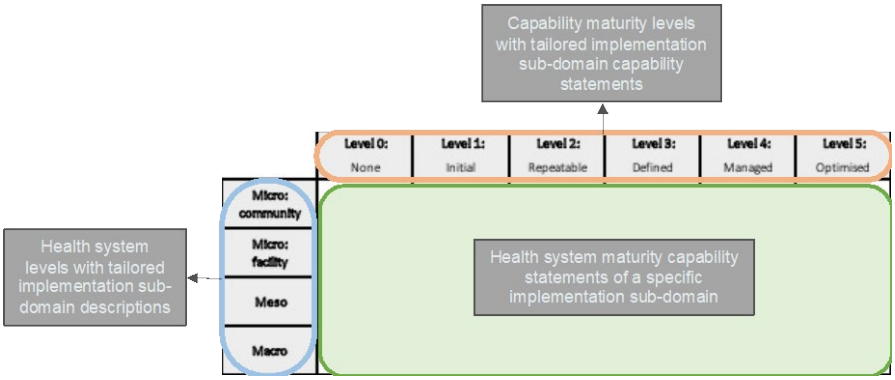

Figure F-4: Components of the maturity model user interface

The preliminary maturity model, as presented in this appendix, is iteratively refined during the verification process (described in Chapter 8) to form the final maturity model, the HII-MM (presented in Chapter 6).

Appendix G HII-MM Supporting Content

This appendix presents the additional information supporting the presentation of the HII-MM in Chapter 6. As depicted in Figure G-1, the HII-MM has three planes. Plane 1, which comprises the domain capability maturity statements, is presented in Section G.1. Plane 2, which comprises the health innovation system description, is presented in Section G.2. Lastly, Plane 3, which comprises the user interfaces, is presented in Section G.3.

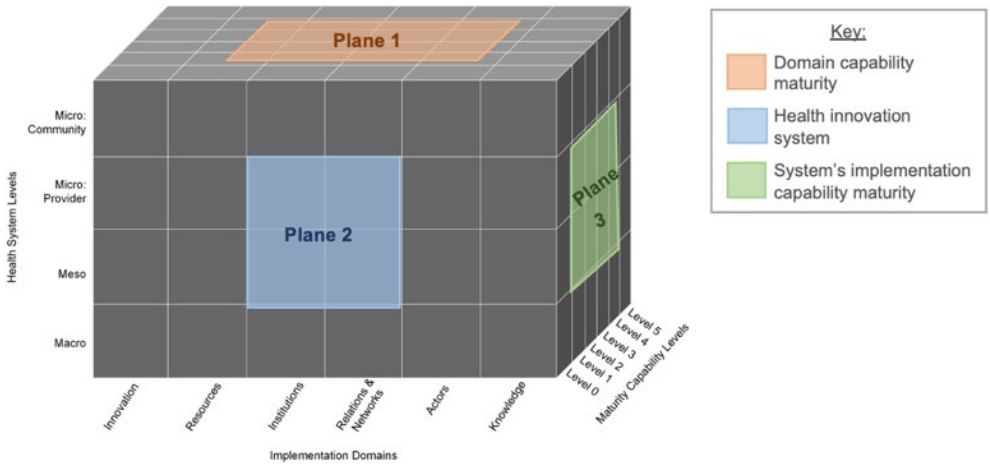

Figure G-1: Conceptual overview of the HII-MM

G.1 Plane 1: Implementation Domain Capability Maturity

Table G-1 shows Plane 1 of the HII-MM. Plane 1 was formed by integrating two dimensions: (i) the implementation domains and (ii) the maturity levels (refer to Section 6.4.1 of Chapter 6).

Table G-1: Implementation domain capability maturity statements

		Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
		None	**Initial**	**Repeatable**	**Defined**	**Managed**	**Optimising**
Innovation	**Design & functionality**	No interoperability, does not function.	Interoperability and functionality are inconsistent.	Partially interoperable, adaptability is controlled.	Interoperable with the system, interoperability and functionality is understood.	Interoperability and functionality within the system are predictable and managed.	Ability to continually adapt to ensure optimal functionality and continuous interoperability.
	Supporting evidence	No evidence supporting the innovation.	Poor/contradicting evidence supporting the innovation.	Evidence supporting the innovation is repeatable, not and contradictory.	Supporting evidence is established / well-defined.	Evidence supporting the innovation is consistently monitored, evaluated and shared.	Innovation is continuously optimised according to internally and externally generated evidence.
	Ethics & equity	Ethics & equity are not considered.	Ethics & equity have been considered. No solutions to the identified ethical and equity concerns.	Solutions to any ethical & equity concerns have been developed. Partial / incomplete implementation of solutions.	Ethical & equity concerns and their solutions are defined, understood and consistently implemented.	Ethical & equity concerns and the implemented solutions are continuously monitored and reported on.	Ethical & equity solutions are optimised according to the changing landscape.
Resources	**Infrastructure, services & physical resources**	Infrastructure, services and physical resources are not present / not available to support the innovation.	Infrastructure, services and physical resources are partially present / available / accessible.	Infrastructure, services and physical resources are entirely available but only temporarily.	Consistent and long-term presence and availability of infrastructure, services and physical resources.	Infrastructure, services and physical resources are reliable and are monitored for quality.	Available Infrastructure, services and physical resources are optimised. Quality is continuously improved.
	Human resources	No human resources present / available.	Inconsistent or insufficient human resources present / available.	Consistent human resources present and available at limited capacity / available temporarily.	Consistent and long-term human resources present and available with sufficient capacity.	Implementation individuals present are continuously monitored.	Implementation individuals present, promote and optimise the innovations longevity.
	Financial resources	No financial resources available.	Inconsistent financial resources available.	Consistent but temporary financial resources available.	Consistent and long-term financial resources available.	Financial resources are monitored to ensure accountability.	Financial resources present are sustainable and promote and optimise innovations longevity.
Institutions	**Laws & regulations**	No laws and regulations supporting the innovation. / Existing laws and regulations prohibit the innovation.	Existing laws and regulations concerning the innovation are contradicting / inconsistent.	Existing laws and regulations concerning the innovation are consistent and supportive of the innovation.	Existing laws and regulations concerning the innovation are established and understood.	Existing laws and regulations concerning the innovation are monitored, actively applied and not influenced by commercial interests.	Existing laws and regulations facilitate and promote the innovation's implementation.

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	Policies	No policies supporting the innovation.	Existing policies concerning the innovation are contradicting / inconsistent.	Existing policies concerning the innovation are consistent and supportive of the innovation.	Existing policies concerning the innovation are established and understood.	Existing policies concerning the innovation are monitored and actively applied.	Policies are continuously improved to facilitate the innovation's implementation and use.
	Standards & guidelines	No standards and guidelines supporting the innovation.	Existing standards and guidelines concerning the innovation are contradicting / inconsistent.	Existing standards and guidelines concerning the innovation are consistent and supportive of the innovation.	Existing standards and guidelines concerning the innovation are established and understood.	Existing standards and guidelines concerning the innovation are monitored and actively applied.	Standards and guidelines are continuously improved to facilitate the innovation's implementation and use, ensuring optimal operation.
	Institutions & priorities	Not in line with institutional priorities. No institutional support / institutional resistance.	Partial alignment with institutional priorities. / Some competing priorities.	Alignment with institutional priorities. Institutional support / acceptance, temporary.	Consistent and long-term institutional support.	Institutional priorities are monitored to ensure accountability and continued alignment.	Institutional priorities promote and optimise the innovation's longevity.
Relations & networks	**Relationship dynamics**	Relationship dynamics hinder the innovation's implementation / use.	Relationships are weak/siloed/disconnected. / Roles and responsibilities are unclear.	Relationships, and roles and responsibilities are clear but not formalised / temporary.	Relationship dynamics, roles and responsibilities are established and formalised, they enable the innovation.	Relationship dynamics are managed and enable accountability.	Relationship dynamics are continually strengthened to optimise the innovation's longevity.
	Collaborations	No collaborations enabling the innovation.	Collaborations are weak / fragmented / siloed.	Effective collaborations exist but they are not formalised / are temporary.	Collaborations are established, understood and long-term.	Collaborations are managed and monitored for quality. Collaborators are held accountable.	Collaborations are continuously improved to promote and optimise the innovation's longevity.
	Evaluation networks	No evaluation networks. / Evaluation networks not used.	Evaluation networks are fragmented / siloed / inconsistent.	Evaluation networks enabling the innovation exist but are temporary.	Evaluation networks are established and understood.	Evaluation networks are monitored for quality and accuracy.	Evaluation networks are optimised to enable the timely incorporation of feedback.
Knowledge	**Dissemination & diffusion**	No awareness of the innovation.	Some awareness of the innovation is a result of informal dissemination or diffusion.	Awareness of the innovation is controlled through dissemination processes.	Dissemination processes are established and formalised. Majority are aware of the innovation.	Dissemination processes are reputable, they are monitored for quality and accuracy.	Dissemination processes are continuously optimised to expand the reach and acceptance of the innovation.
	Knowledge base & capacity	No existing knowledge base.	Fragmented knowledge base of poor quality. Any success is the result of a few individual having the appropriate knowledge base.	The appropriate knowledge base exists in a moderate portion of actors. Knowledge base is new / temporary.	Knowledge base is established in the majority of actors. Knowledge base is long-term.	Knowledge base is routinely monitored for quality.	Knowledge base is continuously improved. The knowledge base is optimised.

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	Education & training	No existing education on the innovation. / No training relating to the innovation provided.	Scarce/inconsistent availability of education/ training relating to the innovation.	Education/training provided is short-term and not-continuous. / Education/ training is provided to a minority of individuals.	Education/training provided is established, consistent and ongoing. / Education/ training is provided to the majority of individuals.	Education/training is routinely evaluated and monitored for quality.	Education/training continually improved to keep up with the changing environment.
Actors	**Culture**	Existing cultural beliefs or practices present in the majority of individuals hinder the innovation. Cultural resistance to the innovation.	Partial, uncontrolled cultural resistance to the innovation or health system.	Innovation is culturally accepted by the majority of individuals. Culture does not contradict the innovation.	The innovation's compatibility with the cultures present is understood and managed.	The innovation's compatibility with the cultures present is continuously monitored and evaluated.	Continuous optimisation initiatives developed and implemented to ensure ongoing cultural relevance.
	Motivations	No motivations present. Disincentives present hinder the innovation.	Inconsistent motivations present. / Disincentives present hinder the innovation in a minority of individuals.	Motivations are understood. Disincentives present are understood and managed.	Motivations are established and managed.	Motivations are predictable and are monitored. There are no unintended consequences.	Strategies to improve motivations are continuously optimised according to the changing landscape.
	Beliefs & attitudes	Beliefs and attitudes surrounding the innovation and health system hinder the innovation. Perceived threats are prevalent.	Uncontrolled beliefs and attitudes about the innovation or health system.	Beliefs and attitudes present among individuals are understood. Perceived threats are understood. Partial / incomplete implementation of solutions.	Beliefs and attitudes are actively managed, attitudes are predictable.	Beliefs and attitudes surrounding the innovation or health system and the implemented solutions are continuously monitored and reported on.	Measures to optimise the positive beliefs and attitudes surrounding the health system or innovation.

G.2 Plane 2: Health Innovation System

Table G-2 shows Plane 2 of the HII-MM. Plane 2 was formed by integrating two dimensions: (i) health system levels and (ii) implementation domains (refer to Section 6.4.2 of Chapter 6).

Table G-2: Health innovation system descriptions

		Micro-level health system		Meso-level health system	Macro-level health system
		Community	**Provider**		
Innovations	**Design & functionality**	Socio-demography of the community. Community's needs / wants.	Existing practices. Socio-demography of providers. Provider's needs / wants.	Meso-level conditions, processes or practices. Meso-level needs / wants.	Macro-level processes or practices. Macro-level needs / wants.
	Supporting evidence	Evidence of benefits to the community.	Evidence of benefits to providers.	Evidence of benefits to meso-level / meso-level population health outcomes.	Evidence of benefits to macro-level / macro-level population health outcomes.
	Ethics & equity	Ethical & equity implications of implementing the innovation on the community.	Ethical & equity implications surrounding the providers using the innovation.	Ethical & equity implications of implementing the innovation on the meso- level.	Ethical & equity implications of implementing the innovation on the macro-level.
Resources	**Infrastructure, services & physical resources**	Infrastructure, services & physical resources enabling the community to access the innovation.	Infrastructure, services & physical resources that enable the providers to use the innovation.	Infrastructure, services & physical resources at meso-level that enable the use of and access to the innovation.	Infrastructure, services & physical resources at macro-level that enable the use of and access to the innovation.
	Human resources	Community members' availability and capacity to support/receive the innovation. Implementation individuals present in the community.	Providers' availability and capacity to support the innovation. Implementation individuals present at the provider-level.	Meso human resources availability and capacity to support the innovation. Implementation individuals present at the meso-level.	Macro human resources availability and capacity to support the innovation. Implementation individuals present at the macro-level.
	Financial resources	Financial resources required for the community to access the innovation.	Financial resources required for the providers to utilise the innovation.	Financial resources required from the meso-level to enable the innovation.	Financial resources required from the macro-level to enable the innovation.
Institutions	**Laws & regulations**	Community-level laws and regulations.	-	Meso-level laws and regulations.	Macro-level laws and regulations.
	Policies	Community-level policies.	Provider-level policies.	Meso-level policies.	Macro-level policies.
	Standards & guidelines	Community-level standards and guidelines.	Provider-level standards and guidelines.	Meso-level standards and guidelines.	Macro-level standards and guidelines.
	Institutions & priorities	Institutions present in the community and their priorities.	Institutions present at the provider-level and their priorities.	Institutions present at the meso-level and their priorities.	Institutions present at the macro-level and their priorities.

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Relations & networks	**Relationship dynamics**	Relationship dynamics within the community-level and between the other health system levels.	Relationship dynamics within the provider-level and between the other health system levels.	Relationship dynamics within the meso-level and between the other health system levels.	Relationship dynamics within the macro-level and between the other health system levels.
	Collaborations	Collaborations within the community-level and between the other health system levels.	Collaborations within the provider-level and between the other health system levels.	Collaborations within the meso-level and between the other health system levels.	Collaborations within the macro-level and between the other health system levels.
	Evaluation networks	Evaluation networks present at the community-level.	Evaluation networks present at the provider-level.	Evaluation networks present at the meso-level.	Evaluation networks present at the macro-level.
Knowledge	**Dissemination & diffusion**	Awareness of the innovation at community-level.	Awareness of the innovation at the provider-level.	Awareness of the innovation at the meso-level.	Awareness of the innovation at the macro-level.
	Knowledge base & capacity	The community's knowledge base and capacity	The providers' knowledge base and capacity	The meso-level knowledge base and capacity	The macro-level knowledge base and capacity
	Education & training	The community's education and training relating to the innovation.	The providers' education and training relating to the innovation.	The meso-level education and training relating to the innovation.	The macro-level education and training relating to the innovation.
Actors	**Culture**	Cultural beliefs or practices present at the community-level.	Cultural beliefs or practices present at the provider-level.	Cultural beliefs or practices present at the meso-level.	Cultural beliefs or practices present at the macro-level.
	Motivations	Motivations present enabling the community to support/receive the innovation.	Motivations present enabling the providers to utilise the innovation.	Motivations present enabling the meso-level to support the innovation.	Motivations present enabling the macro-level to support the innovation.
	Beliefs & attitudes	Community-level beliefs and attitudes of the innovation and health system.	Provider-level beliefs and attitudes of the innovation and health system.	Meso-level beliefs and attitudes of the innovation and health system.	Macro-level beliefs and attitudes of the innovation and health system.

G.3 Plane 3: System's Implementation Capability Maturity

Plane 3 is formed by integrating Plane 1 and Plane 2. The resulting *system's implementation capability maturity* plane forms the basis for the user interfaces (refer to Section 6.4.3 of Chapter 6). Thus, Figure G-2 to Figure G-20 make up Plane 3.

a) Innovation

The innovation domain has three sub-domains, each with a user interface. The user interface for the design & functionality sub-domain is presented in Figure G-2.

Innovation sub-domain: **Design & Functionality**		Maturity Capability Levels					
		Level 0: No interoperability, does not function.	**Level 1:** Interoperability and functionality are inconsistent.	**Level 2:** Partially interoperable, adaptability is controlled.	**Level 3:** Interoperable with the system, interoperability and functionality are understood.	**Level 4:** Interoperability and functionality within the system are predictable and managed.	**Level 5:** Ability to continually adapt to ensure optimal functionality and continuous interoperability.
Health System Levels	**Micro: community** Socio-demography of the community. Community's needs / wants.	No socio-demographic interoperability. / Does not address community needs.	Inconsistent interoperability. / Interoperable with a minority of the community.	Partial interoperability with the community. Some adaptations are needed to improve interoperability.	Fully interoperable with the community. Interoperability understood.	Interoperability of the innovation with the community is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the community.
	Micro: provider Existing practices. Socio-demography of providers. Provider's needs / wants.	No socio-demographic interoperability. / Does not address provider needs. / Not interoperable with existing practices.	Inconsistent interoperability with providers. / Only interoperable with a few providers.	Partial interoperability with providers. Some adaptations are needed to improve interoperability.	Fully interoperable with providers. Interoperability understood.	Interoperability of the innovation with providers is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with providers.
	Meso Meso-level conditions, processes or practices. Meso-level needs / wants.	No interoperability with the meso-level. / Does not address meso-level needs.	Inconsistent or poor interoperability with the meso-level conditions, processes, practices or needs.	Partial interoperability with meso-level conditions, processes or practices. Some adaptations are needed to improve interoperability.	Fully interoperable with meso-level. Interoperability understood.	Interoperability of the innovation with the meso-level is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the changing meso-level.
	Macro Macro-level processes or practices. Macro-level needs / wants.	No interoperability with the macro-level. / Does not address macro needs.	Inconsistent or poor interoperability with macro-level processes, practices or needs.	Partial interoperability with macro-level. Some adaptations are needed to improve interoperability.	Fully interoperable with macro-level, interoperability understood.	Interoperability of the innovation with the macro-level is managed and predictable.	Interoperability is continually assessed to ensure sustained interoperability with the changing macro-level.

Figure G-2: User interface for the innovation sub-domain: design & functionality

The user interface for the supporting evidence sub-domain is presented in Figure G-3.

Innovation sub-domain: **Supporting Evidence**		Maturity Capability Levels					
		Level 0: No evidence supporting the innovation.	**Level 1:** Poor/contradicting evidence supporting the innovation.	**Level 2:** Evidence supporting the innovation is repeatable, not and contradictory.	**Level 3:** Supporting evidence is established / well-defined.	**Level 4:** Evidence supporting the innovation is consistently monitored, evaluated and shared.	**Level 5:** Innovation is continuously optimised according to internally and externally generated evidence.
Health System Levels	**Micro: community** Evidence of benefits to the community.	No evidence supporting the innovations benefits to the community.	Evidence of the innovation's benefits to the community is poor or contradicting.	Evidence of the innovation's benefits to the community is repeatable.	Evidence of the innovation's benefits to the community is established / well-defined.	Evidence of the innovation's benefits to the community is consistently monitored. Evidence is recorded and reported on.	Evidence of the innovation's benefits to the community is used to improve the innovation.
	Micro: provider Evidence of benefits to providers.	No evidence supporting providers using the innovation.	Evidence supporting providers using the innovation is poor or contradicting.	Evidence supporting providers using the innovation is repeatable.	Evidence supporting providers using the innovation is established / well-defined.	Evidence supporting providers using the innovation is consistently monitored. Evidence is recorded and reported on.	Evidence supporting providers using the innovation is used to improve the innovation.
	Meso Evidence of benefits to meso-level / meso-level population health outcomes.	No evidence supporting meso-level benefits /meso-level population health outcomes.	Evidence supporting meso-level benefits / population health outcomes is poor or contradicting.	Evidence supporting the meso-level benefits / population health outcomes is repeatable.	Evidence supporting the meso-level benefits / population health outcomes is established/well-defined.	Evidence supporting meso-level benefits / population health outcomes is consistently monitored. Evidence is recorded and reported on.	Evidence supporting meso-level benefits / population health outcomes is used to improve the innovation.
	Macro Evidence of benefits to macro-level / macro-level population health outcomes.	No evidence supporting macro-level benefits / meso-level population health outcomes.	Evidence supporting macro-level benefits / population health outcomes is poor or contradicting.	Evidence supporting macro-level benefits / population health outcomes is repeatable.	Evidence supporting the macro-level benefits / population health outcomes is established/well-defined.	Evidence supporting macro-level benefits / population health outcomes is consistently monitored. Evidence is recorded and reported on.	Evidence supporting macro-level benefits / population health outcomes is used to improve the innovation.

Figure G-3: User interface for the innovation sub-domain: supporting evidence

The user interface for the ethics & equity sub-domain is presented in Figure G-4.

Innovation sub-domain: **Ethics & Equity user-interface**		Maturity Capability Levels					
		Level 0: Ethics & equity are not considered.	**Level 1:** Ethics & equity have been considered. No solutions to the identified ethical and equity concerns.	**Level 2:** Solutions to any ethical & equity concerns have been developed. Partial / incomplete implementation of solutions.	**Level 3:** Ethical & equity concerns and their solutions are defined, understood and consistently implemented.	**Level 4:** Ethical & equity concerns and the implemented solutions are continuously monitored and reported on.	**Level 5:** Ethical & equity solutions are optimised according to the changing landscape.
Health System Levels	**Micro: community** Ethical & equity implications of implementing the innovation on the community.	Ethical and equity implications on the community are not considered.	Ethical and equity implications on the community are identified. No solutions to the identified concerns.	Solutions to ensure an equitable and ethical innovation for the community are partially / incompletely implemented.	The ethical and equity concerns surrounding the community as well as the solutions to these are defined & understood and consistently implemented.	The community-level ethical and equity concerns are continually monitored and reported on.	The community-level ethical and equity solutions are continually optimised according to the changing landscape.
	Micro: provider Ethical & equity implications surrounding the providers using the innovation.	Ethical and equity implications of providers using the innovation are not considered.	Ethical and equity implications of providers using the innovation are identified. No solutions to the identified concerns.	Solutions to ensure an equitable and ethical innovation for the provider are partially / incompletely implemented.	The provider-level ethical, and equity concerns and their solutions are defined and understood and consistently implemented.	The provider-level ethical and equity concerns are continually monitored and reported on.	The provider-level ethical and equity solutions are continually optimised according to the changing landscape.
	Meso Ethical & equity implications of implementing the innovation on the meso-level.	Ethical and equity implications on the meso-level are not considered.	Ethical and equity implications on the meso-level are identified. No solutions to the identified concerns.	Solutions to ensure an equitable and ethical innovation for the meso-level are partially / incompletely implemented.	The meso-level ethical and equity concerns and their solutions are defined and understood and consistently implemented.	The meso-level ethical and equity concerns are continually monitored and reported on.	The meso-level ethical and equity solutions are continually optimised according to the changing landscape.
	Macro Ethical & equity implications of implementing the innovation on the macro-level.	Ethical and equity implications on the macro-level are not considered.	Ethical and equity implications on the macro-level are identified. No solutions to the identified concerns.	Solutions to ensure an equitable and ethical innovation for the macro-level are partially / incompletely implemented.	The macro-level ethical and equity concerns and their solutions are defined and understood and consistently implemented.	The macro-level ethical and equity concerns are continually monitored and reported on.	The macro-level ethical and equity solutions are continually optimised according to the changing landscape.

Figure G-4: User interface for the innovation sub-domain: ethics & equity

b) Resources

The resources domain has three sub-domains, each with a user interface. The user interface for the infrastructure, services & physical resources sub-domain is presented in Figure G-5.

Resources sub-domain: **Infrastructure, Services & Physical Resources**		Maturity Capability Levels					
		Level 0: Infrastructure, services and physical resources are not present / not available to support the innovation.	**Level 1:** Infrastructure, services and physical resources are partially present / available / accessible.	**Level 2:** Infrastructure, services and physical resources are entirely available but only temporarily.	**Level 3:** Consistent and long-term presence and availability of infrastructure, services and physical resources.	**Level 4:** Infrastructure, services and physical resources are reliable and are monitored for quality.	**Level 5:** Available Infrastructure, services and physical resources are optimised. Quality is continuously improved.
Health System Levels	**Micro: community** Infrastructure, services & physical resources enabling the community to access the innovation.	No infrastructure, services and physical resources present or available to enable the community to access the innovation.	Infrastructure, services and physical resources present / available / accessible that enable the community to access or receive benefits from the innovation are insufficient.	Consistent but temporary infrastructure, services and physical resources are available to enable the community to access or receive benefits from the innovation.	Consistent and long-term infrastructure, services and physical resources available to enable the community to access or receive benefits from the innovation.	Infrastructure, services and physical resources that enable the community to access or receive benefits from the innovation are reliable and monitored for quality.	Infrastructure, services and physical resources that enable the community to access or receive benefits from the innovation are optimised and continuously improved.
	Micro: provider Infrastructure, services & physical resources that enable the providers to use the innovation.	No infrastructure, services and physical resources present or available to enable the providers to use the innovation.	Infrastructure, services and physical resources present / available / accessible that enable the providers to use the innovation are insufficient.	Consistent but temporary infrastructure, services and physical resources available to enable providers to use or implement the innovation.	Consistent and long-term infrastructure, services and physical resources available to enable providers to use or implement the innovation.	Infrastructure, services and physical resources that enable the providers to use the innovation are reliable and monitored for quality.	Infrastructure, services and physical resources that enable the providers to use the innovation are optimised and continuously improved.
	Meso Infrastructure, services & physical resources at meso-level that enable the use of and access to the innovation.	Meso-level infrastructure, services and physical resources that enable the use of and access to the innovation are not present / available.	Meso-level infrastructure, services and physical resources that enable the use of and access to the innovation are only partially present / available / accessible.	Consistent but temporary meso-level infrastructure, services and physical resources available enabling the use or implementation of the innovation.	Consistent and long-term meso-level infrastructure, services and/or physical resources available enabling the use or implementation of the innovation.	Meso-level infrastructure, services and physical resources that enable the use of and access to the innovation are reliable and monitored for quality.	Meso-level infrastructure, services and physical resources that enable the use of and access to the innovation are optimised and continuously improved.
	Macro Infrastructure, services & physical resources at macro-level that enable the use of and access to the innovation.	Macro-level infrastructure, services and physical resources that enable the use of and access to the innovation are not present / available.	Macro-level infrastructure, services and physical resources that enable the use of and access to the innovation are only partially present / available / accessible.	Consistent but temporary macro-level infrastructure, services and physical resources available enabling the use or implementation of the innovation.	Consistent and long-term macro-level infrastructure, services and/or physical resources available enabling the use or implementation of the innovation.	Macro-level infrastructure, services and physical resources that enable the use of and access to the innovation are reliable and monitored for quality.	Macro-level infrastructure, services and physical resources that enable the use of and access to the innovation are optimised and continuously improved.

Figure G-5: User interface for the resources sub-domain: infrastructure, services & physical resources

The user interface for the human resources sub-domain is presented in Figure G-6.

Resources sub-domain: **Human Resources**		Maturity Capability Levels					
		Level 0: No human resources present / available.	**Level 1:** Inconsistent or insufficient human resources present / available.	**Level 2:** Consistent human resources present and available at limited capacity / available temporarily.	**Level 3:** Consistent and long-term human resources present and available with sufficient capacity.	**Level 4:** Implementation individuals present are continuously monitored.	**Level 5:** Implementation individuals present, promote and optimise the innovations longevity.
Health System Levels	**Micro: community** Community members' availability and capacity to support/receive the innovation. Implementation individuals present in the community.	Community members are not present / available to support the innovation.	Inconsistent / insufficient availability of community members supporting the innovation.	Consistent but temporary availability of community members supporting the innovation and acting as implementation individuals.	Consistent and long-term availability of community implementation individuals supporting the innovation. / Consistent and long-term availability of community members receiving the innovation.	Implementation individuals at the community level are continuously monitored to enable the identification of strengths and weaknesses.	Community members supporting the innovation promote and optimise the innovation's longevity.
	Micro: provider Providers' availability and capacity to support the innovation. Implementation individuals present at the provider-level.	Providers are not present / available to support the provision of the innovation.	Inconsistent / insufficient availability of providers supporting the provision of the innovation.	Consistent, but temporary availability of providers supporting the provision of the innovation and acting as implementation individuals.	Consistent and long-term availability and capacity of the providers supporting the provision of the innovation.	Implementation individuals at the provider level are continuously monitored to enable the identification of strengths and weaknesses.	Providers supporting the provision of the innovation promote and optimise the innovation's longevity.
	Meso Meso human resources availability and capacity to support the innovation. Implementation individuals present at the meso-level.	Meso human resources are not present / available to support the innovation.	Inconsistent / insufficient availability of meso-level human resources supporting the innovation.	Consistent but temporary availability of meso-level human resources supporting the innovation and acting as implementation individuals.	Consistent and long-term availability of meso-level human resources supporting the innovation.	Implementation individuals at the meso-level are continuously monitored to enable the identification of strengths and weaknesses.	Meso-level human resources supporting the innovation promote and optimise the innovation's longevity.
	Macro Macro human resources availability and capacity to support the innovation. Implementation individuals present at the macro-level.	Macro human resources are not present / available to support the innovation.	Inconsistent / insufficient availability of macro-level human resources supporting the innovation.	Consistent but temporary availability of macro-level human resources supporting the innovation and acting as implementation individuals.	Consistent and long-term availability of macro-level human resources supporting the innovation.	Implementation individuals at the macro-level are continuously monitored to enable the identification of strengths and weaknesses.	Macro-level human resources supporting the innovation promote and optimise the innovation's longevity.

Figure G-6: User interface for the resources sub-domain: human resources

The user interface for the financial resources sub-domain is presented in Figure G-7.

Resources sub-domain: **Financial Resources**		Maturity Capability Levels					
		Level 0: No financial resources available.	**Level 1:** Inconsistent financial resources available.	**Level 2:** Consistent but temporary financial resources available.	**Level 3:** Consistent and long-term financial resources available.	**Level 4:** Financial resources are monitored to ensure accountability.	**Level 5:** Financial resources present are sustainable and promote and optimise innovations
Health System Levels	**Micro: community** Financial resources required for the community to access the innovation.	Community does not have the financial resources available to access the innovation.	Community has inconsistent financial resources available, enabling inconsistent access to the innovation.	Community has consistent but temporary financial resources available, enabling access to the innovation.	Majority of the community has financial resources available enabling, long-term access to the innovation.	The community's financial resources are not exploited. There is financial accountability surrounding the innovation.	The financial resources required for the community to access the innovation promote and optimise the innovation's longevity.
	Micro: provider Financial resources required for the providers to utilise the innovation.	There are no financial resources available, enabling the provider-level to utilise the innovation.	Inconsistent financial resources available, enabling the provider-level to utilise the innovation.	Consistent but temporary financial resources, available enabling the provider-level to utilise the innovation.	Consistent and long-term financial resources, available enabling the provider-level to utilise the innovation.	There is financial accountability surrounding the facility-level financial resources, enabling the use of the innovation.	Sustainable financial resources available for the providers to utilise the innovation. Financial resources are optimised and promote the innovation's longevity.
	Meso Financial resources required from the meso-level to enable the innovation.	There is no meso-level financial resources available to enable the innovation.	Inconsistent meso-level financial resources available enabling the innovation.	Consistent but temporary meso-level financial resources available enabling the innovation.	Consistent and long-term meso-level financial resources available enabling the innovation.	There is financial accountability surrounding the meso-level financial resources enabling the innovation.	The sustainable financial resources available at the meso-level enabling the innovation. Financial resources are optimised and promote the innovation's longevity.
	Macro Financial resources required from the macro-level to enable the innovation.	There is no macro-level financial resources available to enable the innovation.	Inconsistent macro-level financial resources available enabling the innovation.	Consistent but temporary macro-level financial resources available enabling the innovation.	Consistent and long-term macro-level financial resources available enabling the innovation.	There is financial accountability surrounding the macro-level financial resources enabling the innovation.	The sustainable financial resources available at the meso-level enabling the innovation. Financial resources are optimised and promote the innovation's longevity.

Figure G-7: User interface for the resources sub-domain: financial resources

c) Institutions

The institutions domain has four sub-domains, each with a user interfaces. The user interface for the laws & regulations sub-domain is presented in Figure G-8.

		Maturity Capability Levels					
Institutions sub-domain: **Laws & Regulations**		**Level 0:** No laws and regulations supporting the innovation. / Existing laws and regulations prohibit the innovation.	**Level 1:** Existing laws and regulations concerning the innovation are contradicting / inconsistent.	**Level 2:** Existing laws and regulations concerning the innovation are consistent and supportive of the innovation.	**Level 3:** Existing laws and regulations concerning the innovation are established and understood.	**Level 4:** Existing laws and regulations concerning the innovation are monitored, actively applied and not influenced by commercial interests.	**Level 5:** Existing laws and regulations facilitate and promote the innovation's implementation.
Health System Levels	**Micro: community** Community-level laws and regulations.	No community-level laws and regulations supporting the innovation. / Existing community-level laws and regulations prohibit the innovation.	Existing community-level laws and regulations concerning the innovation are contradicting / inconsistent.	Existing community-level laws and regulations concerning the innovation are consistent and supportive of the innovation.	Existing community-level laws and regulations concerning the innovation are established and understood.	Existing community-level laws and regulations concerning the innovation are monitored, actively applied and autonomous.	Existing community-level laws and regulations facilitate and promote the innovation's implementation.
	Micro: provider						
	Meso Meso-level laws and regulations.	No meso-level laws and regulations supporting the innovation. / Existing meso-level laws and regulations prohibit the innovation.	Existing meso-level laws and regulations concerning the innovation are contradicting / inconsistent.	Existing meso-level laws and regulations concerning the innovation are consistent and supportive of the innovation.	Existing meso-level laws and regulations concerning the innovation are established and understood.	Existing meso-level laws and regulations concerning the innovation are monitored, actively applied and autonomous.	Existing meso-level laws and regulations facilitate and promote the innovation's implementation.
	Macro Macro-level laws and regulations.	No macro-level laws and regulations supporting the innovation. / Existing macro-level laws and regulations prohibit the innovation.	Existing macro-level laws and regulations concerning the innovation are contradicting / inconsistent.	Existing macro-level laws and regulations concerning the innovation are consistent and supportive of the innovation.	Existing macro-level laws and regulations concerning the innovation are established and understood.	Existing macro-level laws and regulations concerning the innovation are monitored, actively applied and autonomous.	Existing macro-level laws and regulations facilitate and promote the innovation's implementation.

Figure G-8: User interface for the institutions sub-domain: laws & regulations

The user interface for the policies sub-domain is presented in Figure G-9.

Institutions sub-domain: **Policies**		Maturity Capability Levels					
		Level 0: No policies supporting the innovation.	**Level 1:** Existing policies concerning the innovation are contradicting / inconsistent.	**Level 2:** Existing policies concerning the innovation are consistent and supportive of the innovation.	**Level 3:** Existing policies concerning the innovation are established and understood.	**Level 4:** Existing policies concerning the innovation are monitored and actively applied.	**Level 5:** Policies are continuously improved to facilitate the innovation's implementation and use.
Health System Levels	**Micro: community** Community-level policies.	No community-level policies supporting the innovation.	Existing community-level policies concerning the innovation are contradicting / inconsistent.	Existing community-level policies concerning the innovation are consistent and supportive of the innovation.	Existing community-level policies concerning the innovation are established and understood.	Existing community-level policies concerning the innovation are monitored and actively applied.	Community-level policies are continuously improved to facilitate the innovation's implementation and use.
	Micro: provider Provider-level policies.	No provider-level policies supporting the innovation.	Existing provider-level policies concerning the innovation are contradicting / inconsistent.	Existing provider-level policies concerning the innovation are consistent and supportive of the innovation.	Existing provider-level policies concerning the innovation are established and understood.	Existing provider-level policies concerning the innovation are monitored and actively applied.	Provider-level policies are continuously improved to facilitate the innovation's implementation and use.
	Meso Meso-level policies.	No meso-level policies supporting the innovation.	Existing meso-level policies concerning the innovation are contradicting / inconsistent.	Existing meso-level policies concerning the innovation are consistent and supportive of the innovation.	Existing meso-level policies concerning the innovation are established and understood.	Existing meso-level policies concerning the innovation are monitored and actively applied.	Meso-level policies are continuously improved to facilitate the innovation's implementation and use.
	Macro Macro-level policies.	No macro-level policies supporting the innovation.	Existing macro-level policies concerning the innovation are contradicting / inconsistent.	Existing macro-level policies concerning the innovation are consistent and supportive of the innovation.	Existing macro-level policies concerning the innovation are established and understood.	Existing macro-level policies concerning the innovation are monitored and actively applied.	Macro-level policies are continuously improved to facilitate the innovation's implementation and use.

Figure G-9: User interface for the institutions sub-domain: policies

The user interface for the standards & guidelines sub-domain is presented in Figure G-10.

Institutions sub-domain: **Standards & Guidelines**		Maturity Capability Levels					
		Level 0: No standards and guidelines supporting the innovation.	**Level 1:** Existing standards and guidelines concerning the innovation are contradicting / inconsistent.	**Level 2:** Existing standards and guidelines concerning the innovation are consistent and supportive of the innovation.	**Level 3:** Existing standards and guidelines concerning the innovation are established and understood.	**Level 4:** Existing standards and guidelines concerning the innovation are monitored and actively applied.	**Level 5:** Standards and guidelines are continuously improved to facilitate the innovation's implementation and use, ensuring optimal operation.
Health System Levels	**Micro: community** Community-level standards and guidelines.	No community-level standards and guidelines supporting the innovation.	Existing community-level standards and guidelines concerning the innovation are contradicting / inconsistent.	Existing community-level standards and guidelines concerning the innovation are consistent and supportive of the innovation.	Existing community-level standards and guidelines concerning the innovation are established and understood.	Existing community-level standards and guidelines concerning the innovation are monitored and actively applied.	Community-level standards and guidelines are continuously improved to facilitate the innovation's implementation and use, ensuring optimal operation.
	Micro: provider Provider-level standards and guidelines.	No provider-level standards and guidelines supporting the innovation.	Existing provider-level standards and guidelines concerning the innovation are contradicting / inconsistent.	Existing provider-level standards and guidelines concerning the innovation are consistent and supportive of the innovation.	Existing provider-level standards and guidelines concerning the innovation are established and understood.	Existing provider-level standards and guidelines concerning the innovation are monitored and actively applied.	Provider-level standards and guidelines are continuously improved to facilitate the innovation's implementation and use, ensuring optimal operation.
	Meso Meso-level standards and guidelines.	No meso-level standards and guidelines supporting the innovation.	Existing meso-level standards and guidelines concerning the innovation are contradicting / inconsistent.	Existing meso-level standards and guidelines concerning the innovation are consistent and supportive of the innovation.	Existing meso-level standards and guidelines concerning the innovation are established and understood.	Existing meso-level standards and guidelines concerning the innovation are monitored and actively applied.	Meso-level standards and guidelines are continuously improved to facilitate the innovation's implementation and use, ensuring optimal operation.
	Macro Macro-level standards and guidelines.	No macro-level standards and guidelines supporting the innovation.	Existing macro-level standards and guidelines concerning the innovation are contradicting / inconsistent.	Existing macro-level standards and guidelines concerning the innovation are consistent and supportive of the innovation.	Existing macro-level standards and guidelines concerning the innovation are established and understood.	Existing macro-level standards and guidelines concerning the innovation are monitored and actively applied.	Macro-level standards and guidelines are continuously improved to facilitate the innovation's implementation and use, ensuring optimal operation.

Figure G-10: User interface for the institutions sub-domain: standards & guidelines

The user interface for the institutions & priorities sub-domain is presented in Figure G-11.

Institutions sub-domain: **Institutions & Priorities**		Maturity Capability Levels					
		Level 0: Not in line with institutional priorities. No institutional support / institutional resistance.	**Level 1:** Partial alignment with institutional priorities. / Some competing priorities.	**Level 2:** Alignment with institutional priorities. Institutional support / acceptance, temporary.	**Level 3:** Consistent and long-term institutional support.	**Level 4:** Institutional priorities are monitored to ensure accountability and continued alignment.	**Level 5:** Institutional priorities promote and optimise the innovation's longevity.
Health System Levels	**Micro: community** Institutions present in the community and their priorities.	Not in line with community-level institutional priorities. No community-level institutional support.	Partial alignment with community-level institutional priorities. / Some competing priorities.	Alignment with community-level institutional priorities. Community-level institutional support / acceptance, temporary.	Consistent and long-term community-level institutional support.	Community-level institutional priorities are monitored to ensure accountability and continued alignment.	Community-level institutional priorities promote and optimise the innovation's longevity.
	Micro: provider Institutions present at the provider-level and their priorities.	Not in line with provider-level institutional priorities. No provider-level institutional support.	Partial alignment with provider-level institutional priorities. / Some competing priorities.	Alignment with provider-level institutional priorities. Provider-level institutional support / acceptance, temporary.	Consistent and long-term provider-level institutional support.	Provider-level institutional priorities are monitored to ensure accountability and continued alignment.	Provider-level institutional priorities promote and optimise the innovation's longevity.
	Meso Institutions present at the meso-level and their priorities.	Not in line with meso-level institutional priorities. No meso-level institutional support.	Partial alignment with meso-level institutional priorities. / Some competing priorities.	Alignment with meso-level institutional priorities. Meso-level institutional support / acceptance, temporary.	Consistent and long-term meso-level institutional support.	Meso-level institutional priorities are monitored to ensure accountability and continued alignment.	Meso-level institutional priorities promote and optimise the innovation's longevity.
	Macro Institutions present at the macro-level and their priorities.	Not in line with macro-level institutional priorities. No macro-level institutional support.	Partial alignment with macro-level institutional priorities. / Some competing priorities.	Alignment with macro-level institutional priorities. Macro-level institutional support / acceptance, temporary.	Consistent and long-term macro-level institutional support.	Macro-level institutional priorities are monitored to ensure accountability and continued alignment.	Macro-level institutional priorities promote and optimise the innovation's longevity.

Figure G-11: User interface for the institutions sub-domain: institutions & priorities

d) Relations & Networks

The relations & networks domain has three sub-domains, each with a user interfaces. The user interface for the relationship dynamics sub-domain is presented in Figure G-12.

Relations & networks sub-domain: **Relationship Dynamics**		Maturity Capability Levels					
		Level 0: Relationship dynamics hinder the innovation's implementation / use.	**Level 1:** Relationships are weak/siloed/disconnected. / Roles and responsibilities are unclear.	**Level 2:** Relationships, and roles and responsibilities are clear but not formalised / temporary.	**Level 3:** Relationship dynamics, roles and responsibilities are established and formalised, they enable the innovation.	**Level 4:** Relationship dynamics are managed and enable accountability.	**Level 5:** Relationship dynamics are continually strengthened to optimise the innovation's longevity.
Health System Levels	**Micro: community** Relationship dynamics within the community-level and between the other health system levels.	Community relationship dynamics hinder the innovation's implementation / use.	Community relationships are weak/siloed/disconnected. / Roles and responsibilities at community-level are unclear.	Community relationships, and roles and responsibilities are clear but not formalised / temporary.	Community relationship dynamics, roles and responsibilities are established and formalised, they enable the innovation.	Community relationship dynamics are managed and enable accountability.	Community relationship dynamics are continually strengthened to optimise the innovation's longevity.
	Micro: provider Relationship dynamics within the provider-level and between the other health system levels.	Provider relationship dynamics hinder the innovation's implementation / use.	Provider relationships are weak/siloed/disconnected. / Roles and responsibilities at provider-level are unclear.	Provider relationships, and roles and responsibilities are clear but not formalised / temporary.	Provider relationship dynamics, roles and responsibilities are established and formalised, they enable the innovation.	Provider relationship dynamics are managed and enable accountability.	Provider relationship dynamics are continually strengthened to optimise the innovation's longevity.
	Meso Relationship dynamics within the meso-level and between the other health system levels.	Meso relationship dynamics hinder the innovation's implementation / use.	Meso relationships are weak/siloed/disconnected. / Roles and responsibilities at meso-level are unclear.	Meso relationships, and roles and responsibilities are clear but not formalised / temporary.	Meso relationship dynamics, roles and responsibilities are established and formalised, they enable the innovation.	Meso relationship dynamics are managed and enable accountability.	Meso relationship dynamics are continually strengthened to optimise the innovation's longevity.
	Macro Relationship dynamics within the macro-level and between the other health system levels.	Macro relationship dynamics hinder the innovation's implementation / use.	Macro relationships are weak/siloed/disconnected. / Roles and responsibilities at macro-level are unclear.	Macro relationships, and roles and responsibilities are clear but not formalised / temporary.	Macro relationship dynamics, roles and responsibilities are established and formalised, they enable the innovation.	Macro relationship dynamics are managed and enable accountability.	Macro relationship dynamics are continually strengthened to optimise the innovation's longevity.

Figure G-12: User interface for the relations & networks sub-domain: relationship dynamics

The user interface for the collaborations sub-domain is presented in Figure G-13.

Relations & networks sub-domain: **Collaborations**		Maturity Capability Levels					
		Level 0: No collaborations enabling the innovation.	**Level 1:** Collaborations are weak / fragmented / siloed.	**Level 2:** Effective collaborations exist but they are not formalised / are temporary.	**Level 3:** Collaborations are established, understood and long-term.	**Level 4:** Collaborations are managed and monitored for quality. Collaborators are held accountable.	**Level 5:** Collaborations are continuously improved to promote and optimise the innovation's longevity.
Health System Levels	**Micro: community** Collaborations within the community-level and between the other health system levels.	No community collaborations enabling the innovation.	Community collaborations are weak / fragmented / siloed.	Effective community-level collaborations exist but they are not formalised / are temporary.	Community collaborations are established, understood and long-term.	Community-level collaborations are managed and monitored for quality. Community collaborators are held accountable.	Community collaborations are continuously improved to promote and optimise the innovation's longevity.
	Micro: provider Collaborations within the provider-level and between the other health system levels.	No provider collaborations enabling the innovation.	Provider collaborations are weak / fragmented / siloed.	Effective provider-level collaborations exist but they are not formalised / are temporary.	Provider collaborations are established, understood and long-term.	Provider-level collaborations are managed and monitored for quality. Provider collaborators are held accountable.	Provider collaborations are continuously improved to promote and optimise the innovation's longevity.
	Meso Collaborations within the meso-level and between the other health system levels.	No meso collaborations enabling the innovation.	Meso collaborations are weak / fragmented / siloed.	Effective meso-level collaborations exist but they are not formalised / are temporary.	Meso collaborations are established, understood and long-term.	Meso-level collaborations are managed and monitored for quality. Meso collaborators are held accountable.	Meso collaborations are continuously improved to promote and optimise the innovation's longevity.
	Macro Collaborations within the macro-level and between the other health system levels.	No macro collaborations enabling the innovation.	Macro collaborations are weak / fragmented / siloed.	Effective macro-level collaborations exist but they are not formalised / are temporary.	Macro collaborations are established, understood and long-term.	Macro-level collaborations are managed and monitored for quality. Macro collaborators are held accountable.	Macro collaborations are continuously improved to promote and optimise the innovation's longevity.

Figure G-13: User interface for the relations & networks sub-domain: collaborations

The user interface for the evaluation networks sub-domain is presented in Figure G-14.

Relations & networks sub-domain: **Evaluation Networks**		Maturity Capability Levels					
		Level 0: No evaluation networks. / Evaluation networks not used.	**Level 1:** Evaluation networks are fragmented / siloed / inconsistent.	**Level 2:** Evaluation networks enabling the innovation exist but are temporary.	**Level 3:** Evaluation networks are established and understood.	**Level 4:** Evaluation networks are monitored for quality and accuracy.	**Level 5:** Evaluation networks are optimised to enable the timely incorporation of feedback.
Health System Levels	**Micro: community** Evaluation networks present at the community-level.	No community-level evaluation networks.	Evaluation networks at the community-level are fragmented / siloed / inconsistent.	Community-level evaluation networks enabling the innovation exist but are temporary.	Evaluation networks at the community-level are established and understood.	Community-level evaluation networks are monitored for quality and accuracy.	Community-level evaluation networks are optimised to enable the timely incorporation of feedback.
	Micro: provider Evaluation networks present at the provider-level.	No provider-level evaluation networks.	Evaluation networks at the provider-level are fragmented / siloed / inconsistent.	Provider-level evaluation networks enabling the innovation exist but are temporary.	Evaluation networks at the provider-level are established and understood.	Provider-level evaluation networks are monitored for quality and accuracy.	Provider-level evaluation networks are optimised to enable the timely incorporation of feedback.
	Meso Evaluation networks present at the meso-level.	No meso-level evaluation networks.	Evaluation networks at the meso-level are fragmented / siloed / inconsistent.	Meso-level evaluation networks enabling the innovation exist but are temporary.	Evaluation networks at the meso-level are established and understood.	Meso-level evaluation networks are monitored for quality and accuracy.	Meso-level evaluation networks are optimised to enable the timely incorporation of feedback.
	Macro Evaluation networks present at the macro-level.	No macro-level evaluation networks.	Evaluation networks at the macro-level are fragmented / siloed / inconsistent.	Macro-level evaluation networks enabling the innovation exist but are temporary.	Evaluation networks at the macro-level are established and understood.	Macro-level evaluation networks are monitored for quality and accuracy.	Macro-level evaluation networks are optimised to enable the timely incorporation of feedback.

Figure G-14: User interface for the relations & networks sub-domain: evaluation networks

e) Knowledge

The knowledge domain has three sub-domains, each with a user interfaces. The user interface for the dissemination & diffusion sub-domain is presented in Figure G-15.

Knowledge sub-domain: **Dissemination & Diffusion**		Maturity Capability Levels					
		Level 0: No awareness of the innovation.	**Level 1:** Some awareness of the innovation is a result of informal dissemination or diffusion.	**Level 2:** Awareness of the innovation is controlled through dissemination processes.	**Level 3:** Dissemination processes are established and formalised. Majority are aware of the innovation.	**Level 4:** Dissemination processes are reputable, they are monitored for quality and accuracy.	**Level 5:** Dissemination processes are continuously optimised to expand the reach and acceptance of the innovation.
Health System Levels	**Micro: community** Awareness of the innovation at community-level.	No awareness of the innovation at the community-level.	Some awareness of the innovation at the community-level is a result of informal dissemination or diffusion.	Awareness of the innovation at the community-level is controlled through dissemination processes.	Dissemination processes at community-level are established and formalised. The majority of the community is aware of the innovation.	Community-level dissemination processes are reputable, they are monitored for quality and accuracy.	Community-level dissemination processes are continuously optimised to expand the reach and acceptance of the innovation.
	Micro: provider Awareness of the innovation at the provider-level.	No awareness of the innovation at the provider-level.	Some awareness of the innovation at the provider-level is a result of informal dissemination or diffusion.	Awareness of the innovation at the provider-level is controlled through dissemination processes.	Dissemination processes at provider-level are established and formalised. The majority of providers are aware of the innovation.	Provider-level dissemination processes are reputable, they are monitored for quality and accuracy.	Provider-level dissemination processes are continuously optimised to expand the reach and acceptance of the innovation.
	Meso Awareness of the innovation at the meso-level.	No awareness of the innovation at the meso-level.	Some awareness of the innovation at the meso-level is a result of informal dissemination or diffusion.	Awareness of the innovation at the meso-level is controlled through dissemination processes.	Dissemination processes at meso-level are established and formalised. The majority of meso-level individuals are aware of the innovation.	Meso-level dissemination processes are reputable, they are monitored for quality and accuracy.	Meso-level dissemination processes are continuously optimised to expand the reach and acceptance of the innovation.
	Macro Awareness of the innovation at the macro-level.	No awareness of the innovation at the macro-level.	Some awareness of the innovation at the macro-level is a result of informal dissemination or diffusion.	Awareness of the innovation at the macro-level is controlled through dissemination processes.	Dissemination processes at macro-level are established and formalised. The majority of macro-level individuals are aware of the innovation.	Macro-level dissemination processes are reputable, they are monitored for quality and accuracy.	Macro-level dissemination processes are continuously optimised to expand the reach and acceptance of the innovation.

Figure G-15: User interface for the knowledge sub-domain: dissemination & diffusion

The user interface for the knowledge base & capacity sub-domain is presented in Figure G-16.

Knowledge sub-domain: **Knowledge Base & Capacity**		Maturity Capability Levels					
		Level 0: No existing knowledge base.	**Level 1:** Fragmented knowledge base of poor quality. Any success is the result of a few individual having the appropriate knowledge base.	**Level 2:** The appropriate knowledge base exists in a moderate portion of actors. Knowledge base is new / temporary.	**Level 3:** Knowledge base is established in the majority of actors. Knowledge base is long-term.	**Level 4:** Knowledge base is routinely monitored for quality.	**Level 5:** Knowledge base is continuously improved. The knowledge base is optimised.
Health System Levels	**Micro: community** The community's knowledge base and capacity	No existing knowledge base at the community-level.	Community knowledge base fragmented and of poor quality.	Quality knowledge base exists in a moderate proportion of the community.	Community knowledge base is established in the majority of actors. Community knowledge base is long-term.	Community knowledge base is routinely monitored for quality.	Community knowledge base is continuously improved. The community knowledge base is optimised.
	Micro: provider The providers' knowledge base and capacity	No existing knowledge base at the provider-level.	Provider knowledge base fragmented and of poor quality.	Quality knowledge base exists in a moderate proportion of the providers.	Provider knowledge base is established in the majority of actors. Provider knowledge base is long-term.	Provider knowledge base is routinely monitored for quality.	Provider knowledge base is continuously improved. The provider knowledge base is optimised.
	Meso The meso-level knowledge base and capacity	No existing knowledge base at the meso-level.	Meso-level knowledge base fragmented and of poor quality.	Quality knowledge base exists in a moderate proportion of the meso-level.	Meso-level knowledge base is established in the majority of actors. Meso-level knowledge base is long-term.	Meso-level knowledge base is routinely monitored for quality.	Meso-level knowledge base is continuously improved. The meso-level knowledge base is optimised.
	Macro The macro-level knowledge base and capacity	No existing knowledge base at the macro-level.	Macro-level knowledge base fragmented and of poor quality.	Quality knowledge base exists in a moderate proportion of the macro-level.	Macro-level knowledge base is established in the majority of actors. Macro-level knowledge base is long-term.	Macro-level knowledge base is routinely monitored for quality.	Macro-level knowledge base is continuously improved. The macro-level knowledge base is optimised.

Figure G-16: User interface for the knowledge sub-domain: knowledge base & capacity

The user interface for the education & training sub-domain is presented in Figure G-17.

Knowledge sub-domain: Education & Training		Maturity Capability Levels					
		Level 0: No existing education on the innovation. / No training relating to the innovation provided.	**Level 1:** Scarce/inconsistent availability of education/ training relating to the innovation.	**Level 2:** Education/training provided is short-term and not-continuous. / Education/ training is provided to a minority of individuals.	**Level 3:** Education/training provided is established, consistent and ongoing. / Education/ training is provided to the majority of individuals.	**Level 4:** Education/training is routinely evaluated and monitored for quality.	**Level 5:** Education/training continually improved to keep up with the changing environment.
Health System Levels	**Micro: community** The community's education and training relating to the innovation.	No existing education on the innovation at the community-level. / No community training relating to the innovation provided.	Scarce/inconsistent availability of education/ training relating to the innovation at the community-level.	Education/training provided at community-level is short-term and not-continuous. / Education/training is provided to a minority of individuals in the community.	Community education/training provided is established, consistent and ongoing. / Education/training is provided to the majority of individuals in the community.	Community education/training is routinely evaluated and monitored for quality.	Community education/training continually improved to keep up with the changing environment.
	Micro: provider The providers' education and training relating to the innovation.	No existing education on the innovation at the provider-level. / No provider training relating to the innovation provided.	Scarce/inconsistent availability of education/ training relating to the innovation at the provider-level.	Education/training provided at provider-level is short-term and not-continuous. / Education/training is provided to a minority of individuals at the provider-level.	Provider education/training provided is established, consistent and ongoing. / Education/training is provided to the majority of individuals at the provider-level.	Provider education/training is routinely evaluated and monitored for quality.	Provider education/training continually improved to keep up with the changing environment.
	Meso The meso-level education and training relating to the innovation.	No existing education on the innovation at the meso-level. / No meso training relating to the innovation provided.	Scarce/inconsistent availability of education/ training relating to the innovation at the meso-level.	Education/training provided at meso-level is short-term and not-continuous. / Education/training is provided to a minority of individuals at the meso-level.	Meso education/training provided is established, consistent and ongoing. / Education/training is provided to the majority of individuals at the meso-level.	Meso education/training is routinely evaluated and monitored for quality.	Meso education/training continually improved to keep up with the changing environment.
	Macro The macro-level education and training relating to the innovation.	No existing education on the innovation at the macro-level. / No macro training relating to the innovation provided.	Scarce/inconsistent availability of education/ training relating to the innovation at the macro-level.	Education/training provided at macro-level is short-term and not-continuous. / Education/training is provided to a minority of individuals at the macro-level.	Macro education/training provided is established, consistent and ongoing. / Education/training is provided to the majority of individuals at the macro-level.	Macro education/training is routinely evaluated and monitored for quality.	Macro education/training continually improved to keep up with the changing environment.

Figure G-17: User interface for the knowledge sub-domain: education & training

f) Actors

The actors domain user interfaces has three sub-domains, each with a user interfaces. The user interface for the culture sub-domain is presented in Figure G-18.

Actors sub-domain: Culture		Maturity Capability Levels					
		Level 0: Existing cultural beliefs or practices present in the majority of individuals hinder the innovation. Cultural resistance to the innovation.	**Level 1:** Partial, uncontrolled cultural resistance to the innovation or health system.	**Level 2:** Innovation is culturally accepted by the majority of individuals. Culture does not contradict the innovation.	**Level 3:** The innovation's compatibility with the cultures present is understood and managed.	**Level 4:** The innovation's compatibility with the cultures present is continuously monitored and evaluated.	**Level 5:** Continuous optimisation initiatives developed and implemented to ensure ongoing cultural relevance.
Health System Levels	**Micro: community** Cultural beliefs or practices present at the community-level.	Existing community-level cultural beliefs or practices present in the majority of individuals hinder the innovation. Community-level cultural resistance to the innovation.	Partial, uncontrolled cultural resistance to the innovation or health system at the community level.	Innovation is culturally accepted by the majority of individuals at the community-level. Community-level culture does not contradict the innovation.	The innovation's compatibility with the cultures present at the community-level is understood and managed.	The innovation's compatibility with the cultures present in the community-level is continuously monitored and evaluated.	Continuous optimisation initiatives developed and implemented to ensure ongoing community-level cultural relevance.
	Micro: provider Cultural beliefs or practices present at the provider-level.	Existing provider-level cultural beliefs or practices present in the majority of individuals hinder the innovation. Provider-level cultural resistance to the innovation.	Partial, uncontrolled cultural resistance to the innovation or health system at the provider-level.	Innovation is culturally accepted by the majority of individuals at the provider-level. Provider-level culture does not contradict the innovation.	The innovation's compatibility with the cultures present at the provider-level is understood and managed.	The innovation's compatibility with the cultures present in the provider-level is continuously monitored and evaluated.	Continuous optimisation initiatives developed and implemented to ensure ongoing provider-level cultural relevance.
	Meso Cultural beliefs or practices present at the meso-level.	Existing meso-level cultural beliefs or practices present in the majority of individuals hinder the innovation. Meso-level cultural resistance to the innovation.	Partial, uncontrolled cultural resistance to the innovation or health system at the meso-level.	Innovation is culturally accepted by the majority of individuals at the meso-level. Meso-level culture does not contradict the innovation.	The innovation's compatibility with the cultures present at the meso-level is understood and managed.	The innovation's compatibility with the cultures present in the meso-level is continuously monitored and evaluated.	Continuous optimisation initiatives developed and implemented to ensure ongoing meso-level cultural relevance.
	Macro Cultural beliefs or practices present at the macro-level.	Existing macro-level cultural beliefs or practices present in the majority of individuals hinder the innovation. Macro-level cultural resistance to the innovation.	Partial, uncontrolled cultural resistance to the innovation or health system at the macro-level.	Innovation is culturally accepted by the majority of individuals at the macro-level. Macro-level culture does not contradict the innovation.	The innovation's compatibility with the cultures present at the macro-level is understood and managed.	The innovation's compatibility with the cultures present in the macro-level is continuously monitored and evaluated.	Continuous optimisation initiatives developed and implemented to ensure ongoing macro-level cultural relevance.

Figure G-18: User interface for the actors sub-domain: culture

The user interface for the motivations sub-domain is presented in Figure G-19.

	Actors sub-domain: **Motivations**	Maturity Capability Levels					
		Level 0: No motivations present. Disincentives present hinder the innovation.	**Level 1:** Inconsistent motivations present. / Disincentives present hinder the innovation in a minority of individuals.	**Level 2:** Motivations are understood. Disincentives present are understood and managed.	**Level 3:** Motivations are established and managed.	**Level 4:** Motivations are predictable and are monitored. There are no unintended consequences.	**Level 5:** Strategies to improve motivations are continuously optimised according to the changing landscape.
Health System Levels	**Micro: community** Motivations present enabling the community to support/receive the innovation.	No community-level motivations present. Community-level disincentives present hinder the innovation.	Inconsistent community-level motivations present. / Community-level disincentives present hinder the innovation in a minority of individuals.	Community-level motivations are understood. Community-level disincentives present are understood and managed.	Community-level motivations are established and managed.	Community-level motivations are predictable and are monitored. There are no unintended consequences.	Strategies to improve community-level motivations are continuously optimised according to the changing landscape.
	Micro: provider Motivations present enabling the providers to utilise the innovation.	No provider-level motivations present. Provider-level disincentives present hinder the innovation.	Inconsistent provider-level motivations present. / Provider-level disincentives present hinder the innovation in a minority of individuals.	Provider-level motivations are understood. Provider-level disincentives present are understood and managed.	Provider-level motivations are established and managed.	Provider-level motivations are predictable and are monitored. There are no unintended consequences.	Strategies to improve provider-level motivations are continuously optimised according to the changing landscape.
	Meso Motivations present enabling the meso-level to support the innovation.	No meso-level motivations present. Meso-level disincentives present hinder the innovation.	Inconsistent meso-level motivations present. / Meso-level disincentives present hinder the innovation in a minority of individuals.	Meso-level motivations are understood. Meso-level disincentives present are understood and managed.	Meso-level motivations are established and managed.	Meso-level motivations are predictable and are monitored. There are no unintended consequences.	Strategies to improve meso-level motivations are continuously optimised according to the changing landscape.
	Macro Motivations present enabling the macro-level to support the innovation.	No macro-level motivations present. Macro-level disincentives present hinder the innovation.	Inconsistent macro-level motivations present. / Macro-level disincentives present hinder the innovation in a minority of individuals.	Macro-level motivations are understood. Macro-level disincentives present are understood and managed.	Macro-level motivations are established and managed.	Macro-level motivations are predictable and are monitored. There are no unintended consequences.	Strategies to improve macro-level motivations are continuously optimised according to the changing landscape.

Figure G-19: User interface for the actors sub-domain: motivations

The user interface for the beliefs & attitudes sub-domain is presented in Figure G-20.

	Actors sub-domain: **Beliefs & Attitudes**	Maturity Capability Levels					
		Level 0: Beliefs and attitudes surrounding the innovation and health system hinder the innovation. Perceived threats are prevalent.	**Level 1:** Uncontrolled beliefs and attitudes about the innovation or health system.	**Level 2:** Beliefs and attitudes present among individuals are understood. Perceived threats are understood. Partial / incomplete implementation of solutions.	**Level 3:** Beliefs and attitudes are actively managed, attitudes are predictable.	**Level 4:** Beliefs and attitudes surrounding the innovation or health system and the implemented solutions are continuously monitored and reported on.	**Level 5:** Measures to optimise the positive beliefs and attitudes surrounding the health system or innovation.
Health System Levels	**Micro: community** Community-level beliefs and attitudes of the innovation and health system.	Community-level beliefs and attitudes surrounding the innovation and health system hinder the innovation. Perceived threats are prevalent.	Uncontrolled community-level beliefs and attitudes about the innovation or health system.	Community-level beliefs and attitudes present among individuals are understood. Perceived threats at community-level are understood. Partial / incomplete implementation of solutions.	Community-level beliefs and attitudes are actively managed, attitudes are predictable.	Community-level beliefs and attitudes surrounding the innovation or health system and the implemented solutions are continuously monitored and reported on.	Measures are implemented to optimise positive community-level beliefs and attitudes surrounding the health system or innovation.
	Micro: provider Provider-level beliefs and attitudes of the innovation and health system.	Provider-level beliefs and attitudes surrounding the innovation and health system hinder the innovation. Perceived threats are prevalent.	Uncontrolled provider-level beliefs and attitudes about the innovation or health system.	Provider-level beliefs and attitudes present among individuals are understood. Perceived threats at provider level are understood. Partial / incomplete implementation of solutions.	Provider-level beliefs and attitudes are actively managed, attitudes are predictable.	Provider-level beliefs and attitudes surrounding the innovation or health system and the implemented solutions are continuously monitored and reported on.	Measures are implemented to optimise positive provider-level beliefs and attitudes surrounding the health system or innovation.
	Meso Meso-level beliefs and attitudes of the innovation and health system.	Meso-level beliefs and attitudes surrounding the innovation and health system hinder the innovation. Perceived threats are prevalent.	Uncontrolled meso-level beliefs and attitudes about the innovation or health system.	Meso-level beliefs and attitudes present among individuals are understood. Perceived threats at meso-level are understood. Partial / incomplete implementation of solutions.	Meso-level beliefs and attitudes are actively managed, attitudes are predictable.	Meso-level beliefs and attitudes surrounding the innovation or health system and the implemented solutions are continuously monitored and reported on.	Measures are implemented to optimise positive meso-level beliefs and attitudes surrounding the health system or innovation.
	Macro Macro-level beliefs and attitudes of the innovation and health system.	Macro-level beliefs and attitudes surrounding the innovation and health system hinder the innovation. Perceived threats are prevalent.	Uncontrolled macro-level beliefs and attitudes about the innovation or health system.	Macro-level beliefs and attitudes present among individuals are understood. Perceived threats at macro-level are understood. Partial / incomplete implementation of solutions.	Macro-level beliefs and attitudes are actively managed, attitudes are predictable.	Macro-level beliefs and attitudes surrounding the innovation or health system and the implemented solutions are continuously monitored and reported on.	Measures are implemented to optimise positive macro-level beliefs and attitudes surrounding the health system or innovation.

Figure G-20: User interface for the actors sub-domain: beliefs & attitudes

Appendix H Operationalising the HII-MM

This appendix presents components of the operationalised HII-MM, which is described in Chapter 7. The operationalised HII-MM takes the form of an excel model. The first four sections describe the introductory worksheets; in Section H.1, the landing tab is presented, in Section H.2, the FAQs are presented, and in Section H.3, the index is presented. Following the introductory tabs, there is one worksheet that describes the instructions on how to use the operationalised HII-MM; these are presented in Section H.4.

The next 32 worksheets are the user interfaces, of which 20 allow user input. The HII-MM's first user interface relates to general considerations and is presented in Section H.5. Then, there is a set of implementation domain user interfaces for each of the six domains (refer to Chapter 7, Section 7.4). The comprehensive set of implementation domain user interfaces is not presented here as they overlap with the interfaces presented in Appendix G, Section G.3.

Lastly, the operationalised HII-MM comprises three concluding worksheets. Section H.7 presents the worksheet that presents an overall summary of the maturity results. Section H.8 presents the worksheet containing a list of potential implementation strategies. Section H.9 presents the worksheet containing the list of references referred to throughout the Excel workbook.

H.1 Introduction

Figure H-1 shows the landing page of the operationalised HII-MM.

The Low- and Middle-Income Country Health Innovation Implementation Maturity Model (HII-MM)

This model forms part of a larger project: a PhD dissertation, "Evaluating the successful and sustainable implementation of evidence-based innovations in health systems in low- and middle-income countries: a maturity model approach".

Introduction

The HII-MM is a maturity assessment tool that facilitates the assessment of low- and middle-income country (LMIC) health systems; it defines the system's current implementation maturity and provides potential improvement or maturation paths. The aim of the HII-MM is to promote and improve the successful and sustainable implementation of evidence-based health innovations into LMIC health systems. Implementation is "*the use of strategies to adopt and integrate*" evidence-based health innovations in a specific context (Proctor, Powell and McGinnis, 2017). Sustainable implementation can be described as the extent to which the innovation can continue over time and be assimilated into the specific context (Iwelunmor et al., 2016).

The HII-MM was developed through extensive multi-disciplinary literature reviews and an evaluation process involving subject matter experts from 21 different LMICs. The HII-MM lies in the intersection of three major themes, namely, (i) health innovation systems, (ii) implementation, and (iii) the LMIC context; thus, the model's focus is the implementation of evidence-based innovations in LMIC health innovation systems. A list of publications supporting the development of the HII-MM is listed at the end of this page. The HII-MM consists of three dimensions: ***implementation domains, health system levels*** and ***maturity levels***. Each of these dimensions is introduced below.

***Note**: This document is intended as a guide. It is unnecessary to get answers for every question or user interface, nor should you feel limited by these questions. The results of this assessment are meant to determine gaps and strengths in the health innovation landscape being assessed, not to judge performance. Due to health systems' complex and dynamic nature, using the HII-MM cannot guarantee an improved implementation process.*

Implementation domains

The implementation domains are the broad concepts identified as facilitators or barriers when implementing an evidence-based innovation in an LMIC context. The HII-MM has six implementation domains which provide a **holistic view of the 'hard' and 'soft' concepts in a health innovation system that may impact an implementation process**. The implementation domains are further broken down into sub-domains to allow for a more detailed understanding of the system. An overview of the implementation domains and sub-domains is provided in the table below. All of the domains are interrelated and can be assessed in any order. It is advised that all sub-domains are considered during the assessment; however, there is a N/A option that can be used.

Innovation Domain	Within the innovation domain, the actual **evidence-based health innovation is being considered.** A health innovation, which can also be referred to as a health intervention, is any new "*concept, idea, service, process, or product*" which aims to improve some aspect of health, including health education, treatments, prevention, diagnosis, outreach or research (Omachonu and Einspruch, 2010, p.5). Within the innovation domain, four sub-domains should be assessed: i. Design: the features of the innovation, specifically concerning the interoperability of the features with the setting into which the innovation is being implemented. ii. Functionality: how the innovation functions, what it is supposed to do and what it actually does. iii. Supporting evidence: the information supporting the validity of the innovation. iv. Ethics & equity: any ethical or equity-related implications of the innovation and the implementation process.
Resources Domain	The resources domain refers to the **assets present within the health innovation system.** Within the resources domain, three sub-domains should be assessed: i. Infrastructure & physical resources: the existing infrastructure and resources present and available in the system. This includes information systems, technological infrastructure, pharmaceuticals, health system supplies etc. ii. Human Resources: the presence or absence of specific individuals within the system and during the implementation process. iii. Financial Resources: any monetary aspects involved during the implementation process.
Institutions Domain	The institutions domain refers to the **rules, laws and practices that shape interactions within the health innovation landscape**. The roles of institutions are to guide and oversee the health system and protect the population who use and who are part of the health system (World Health Organization, 2007). Within the institutions domain, three sub-domains should be assessed: i. Institutions & priorities: the institutions present, political climate, and priorities of the health system stakeholders. ii. Laws & regulations: the mandatory legislation that governs a system. iii. Policies: a group of plans and ideas agreed on by an organisation. iv. Standards & guidelines: any documentation that guides the use of an innovation or guides different aspects of the implementation process.
Relations and Networks Domain	The relations and networks domain considers the **links between groups of actors within and between different health system levels.** Within the relations and networks domain, three sub-domains should be assessed: i. Relationships & leadership: the relationships and leadership structures present within and between different health system levels. ii. Collaborations: any joint endeavour between two or more stakeholders. iii. Evaluation, feedback & communication: communication, evaluation and feedback practices within and between different health system levels.

Figure H-1: Operationalised HII-MM landing page

Actors Domain	The actors domain is the **sociology of the people participating in the health system's actions or processes.** It differs from the human resources domain as it considers the 'soft' aspects of people, whereas human resources simply consider the presence or absence of people. Within the actors domain, three sub-domains should be assessed: i. Culture: the customs, way of life or social organisation shared between a particular group. ii. Motivations: the actors' motivations are assessed in terms of explicit and indirect incentives and disincentives. iii. Attitudes: the beliefs that actors have influenced the actor's attitudes towards the health system, innovation and implementation process.
Knowledge Domains	The knowledge domain refers to the **information and understanding actors have of the various aspects of the implementation process.** Within the knowledge domain, there are three sub-domains that should be assessed: i. Knowledge base & capacity: the knowledge base comprises the expertise and skills a person has, and knowledge capacity considers the number of people in an organisation or system with the necessary knowledge base to use or implement the innovation. ii. Education: any process that facilitates learning among the actors present; this includes the availability of training for the innovation, mentoring, change management processes, the medical curriculum in the country and health education in a country. iii. Dissemination & diffusion: the active and passive spread of information surrounding the innovation or the implementation process.

The model has been developed to be adaptable to the different phases of the implementation process. In each implementation domain user interface, a discussion of the interface's applicability to the phases of an implementation process is provided. The implementation process combines the innovation adoption process described by Tidd and Bessant (2009) and the health-specific implementation process described by Aarons, Hurlburt and Mccue Horwitz (2011). **The implementation phases used in this model are (i) searching for, selecting or designing an innovation, (ii) implementation preparation, (iii) implementing the innovation, and (iv) sustaining the innovation.**

Health system levels

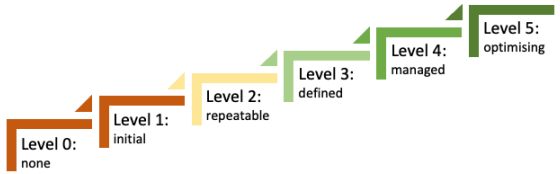
The method chosen to describe the HII-MM health system levels is ***levels of analysis***. The maturity model has four levels of analysis which can be adapted to befit different assessment contexts.

The levels are (i) **micro-community level,** which includes the members of the population members who are the recipients or beneficiaries of the innovation being assessed; (ii) **micro-provider level,** which considers the health workers who are tasked with utilising the innovation; (iii) **meso level** is an entity below the national level and will vary depending on the specific context being assessed; and (iii) **macro level** is the first tier of a countries government, there is however flexibility for the macro level to be an entity below the national level, but above the meso level, this is to cater for countries with autonomous sub-national levels.

The implementation domains and sub-domains are present within each health system level (refer to the vertical axes of the user interfaces). For example, within the *infrastructure & physical resources* sub-domain, the micro-community health system level covers the resources enabling community members to access the innovation; the micro-provider health system level covers the resources available to the health provider that enable them to use the innovation, and the meso and macro health system levels cover the presence and availability of the physical and infrastructural resources provided by the respective levels that enable the success of the innovation.

The health system levels interact with and influence one another. The health system levels will have varying levels of influence on the implementation process and the implementation domains. While it is advised to consider each health system level to ensure a systems thinking perspective is taken during the assessment, there will be innovations or contexts where health system levels are not applicable.

Maturity levels



Maturity models illustrate a direction for development towards a desired state (Mettler and Blondiau, 2012); they are beneficial in assisting decision-makers in prioritising improvements (Poeppelbuss et al., 2011). The assessment measure used in maturity models is maturity levels. **Maturity levels are statements that enable the understanding of the capability of a system to implement an innovation; the maturity levels outline an evolutionary path for improvement.** The maturity levels used to develop the HII-MM are structured according to the well-known CMM (see the above figure) developed by the CMMI Product Team (2008). The generic maturity levels described in the CMM are customised for each implementation sub-domain (refer to the horizontal axes of the user interfaces). Six maturity levels are used for the HII-MM; maturity Level 0 represents the lowest, least optimal maturity level, and Level 5 represents the highest, most optimal level of maturity. Lower maturity levels indicate a higher chance that the innovation implementation process is unsuccessful, and higher maturity levels indicate a higher chance for the successful and sustainable implementation of the innovation. Maturity levels are cumulative; therefore, to progress to the next level, the characteristics of the previous levels must first be met.

Supporting Publications

Leonard, E., De Kock, I. and Bam, W. (2018) 'Development of a Health System Framework to Guide the Analysis of Innovation Adoption in Low and Middle Income Countries', in *SAIIE29 Proceedings*, pp. 91–104.

Leonard, E., De Kock, I. and Bam, W. (2019) 'Investigating the relationships between health and innovation systems to guide innovation adoption', in *2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*. IEEE. doi: 10.1109/ICE.2019.8792677.

Leonard, E., De Kock, I. and Bam, W. (2020a) 'Barriers and facilitators to implementing evidence-based health innovations in low- and middle-income countries: A systematic literature review', *Evaluation and Program Planning*, 82. doi: 10.1016/j.evalprogplan.2020.101832.

Leonard, E., De Kock, I. and Bam, W. (2020b) 'Investigating the barriers and facilitators to implementing an eHealth innovation into a resource-constrained setting: A South African case study', in *Proceedings - 2020 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2020*. doi: 10.1109/ICE/ITMC49519.2020.9198648.

Figure H-1 (cont.): Operationalised HII-MM landing page

H.2 FAQs

Figure H-2 shows the list of FAQs surrounding the HII-MM.

Frequently asked questions

1. What is a maturity model?

Maturity models are multi-staged models which detail the evolution from an initial to a mature state of an organisation's, individual's or systems' capabilities. They illustrate a direction for development towards a desired state.

2. What is the HII-MM?

The HII-MM is an assessment framework that supports the successful and sustainable implementation of evidence-based health innovations in low- and middle-income countries.

3. Who is the model for?

The intended audience of the maturity model includes health system stakeholders involved with any stage of an innovation implementation process. This could include NGOs, academic institutions, health officials, health system regulators, providers, suppliers, payers and patients. The intended audience will vary depending on the application areas and drivers of conducting the maturity assessment.

4. Are there any costs associated with the model?

There are no direct costs of using the model. The indirect costs associated with using the model include employees' time and possible travel costs.

5. How do I conduct the maturity assessment?

Detailed instructions on how to use the HII-MM can be found here. The maturity model consists of user interfaces which work like marking rubrics. Within the user interfaces, each maturity level has a description. A set of guiding questions are provided to support the user in collecting data, which is then used to determine which description is most applicable to the situation being assessed.

6. What data sources should I use?

Relevant data sources include, but are not limited to, policy documents, population census data, peer-reviewed journal articles and interviews with stakeholders (including the community, health workers, policymakers, project managers, the innovation company etc.). Specific data sources are discussed in the user interface for each sub-domain.

7. What happens after the assessment?

You can use the results to develop a strategy to address the weak areas identified in the innovation, health system or implementation methods. The results obtained from the maturity assessment should be analysed, synthesised and presented to the relevant stakeholders.

8. Why does the HII-MM not include all WHO health system building blocks?

The HII-MM covers all of the concepts present in a health innovation system. As a result, some health system building blocks are not explicitly mentioned as a domain or sub-domain. E.g. there is no separate information systems domain; however, information systems are implicitly covered throughout the domains and sub-domains.

OVERVIEW

INDEX

Figure H-2: Operationalised HII-MM FAQs

H.3 Index

Figure H-3 shows the index of the operationalised HII-MM.

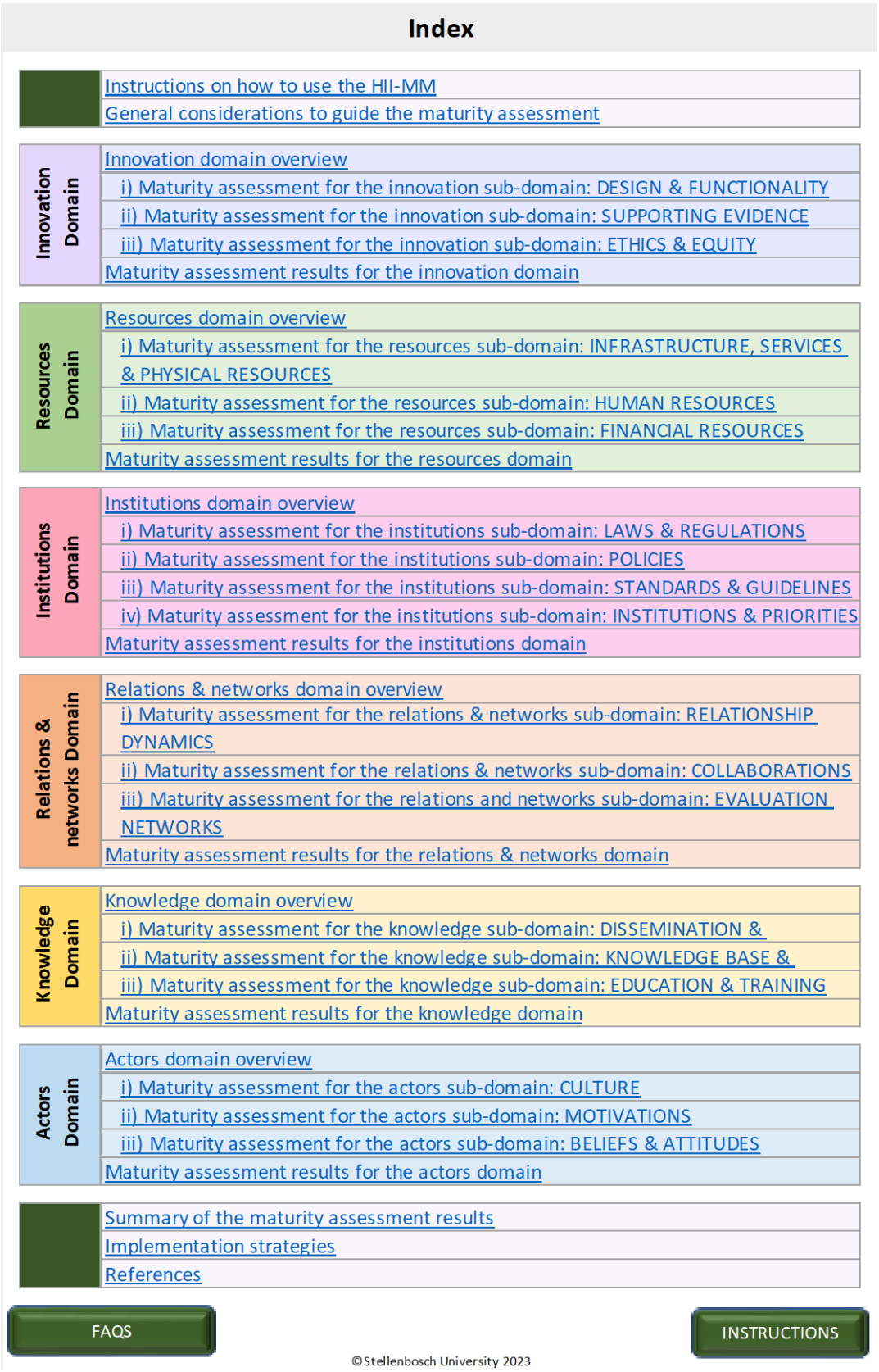


Figure H-3: Operationalised HII-MM index

H.4 Instructions

Figure H-4 shows the instructions that describe how to use the operationalised HII-MM.

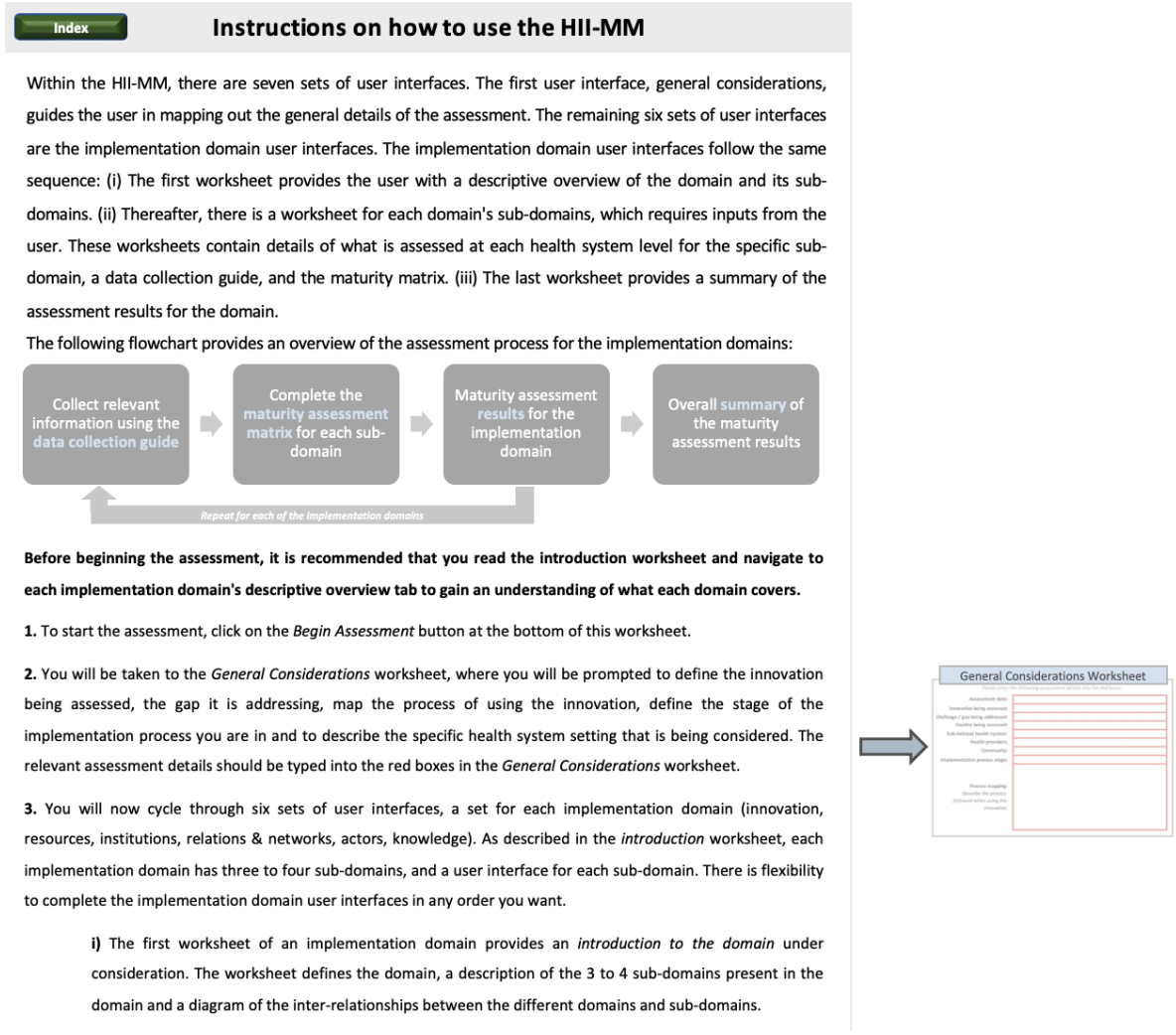


Figure H-4: Operationalised HII-MM instructions

ii) The worksheets following the *introduction to the domain* are the *domain user interfaces*. Each domain has 3 to 4 user interfaces, one for each sub-domain.

- The sub-domain user interface begins with a discussion about what the sub-domain entails.

- Then, a *Data Collection Guide* is presented, the objective of which is to guide the information collection process. Data should be collected from a variety of sources to reduce bias and enable greater accuracy.

- The data collected using the *Data Collection Guide* should enable the user to complete the *Maturity Assessment Matrix*. The matrix is presented just below the *Data Collection Guide*; each sub-domain has a specific *Maturity Assessment Matrix*. The health system levels are described on the vertical axis of the matrix, and on the horizontal axis the maturity levels are described. The matrix body matrix comprises capability statements that describe possible states that a system, innovation or implementation process could be at. The matrix works like a marking rubric; the data collected for a sub-domain should be used to determine which capability statement is most applicable to the situation being assessed:

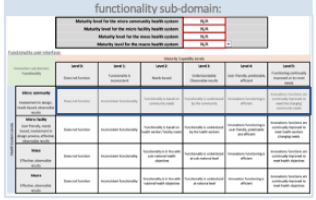
1. *Within the sub-domain being assessed, consider one health system level at a time; **read each capability statement** within the health system level (statements for maturity levels 0 to 5).*

2. *__Identify the statement most applicable__ to the current state of the system/innovation/implementation process being assessed; this statement will correspond with a maturity level (refer to the horizontal axis).*

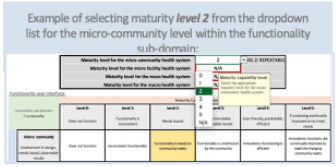
3. *Having identified the most applicable maturity level, using the red boxes, which are situated just above the matrix, **select the identified level using the dropdown list.** If you deem the health system level or sub-domain irrelevant, you can select the 'N/A' option from the dropdown list.*

4. *Follow the same process for each health system level within the sub-domain, then move to the next sub-domain.*

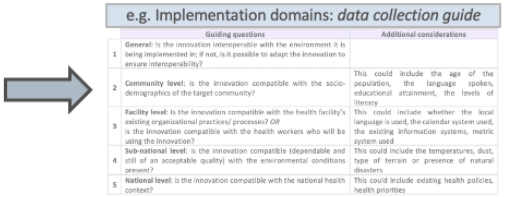
Illustration of the capability statements that should be considered for the micro-community level within the functionality sub-domain:



Example of selecting maturity ***level 2*** from the dropdown list for the micro-community level within the functionality sub-domain:



e.g. Implementation domains: *data collection guide*



e.g. Implementation domains: *maturity assessment matrix*

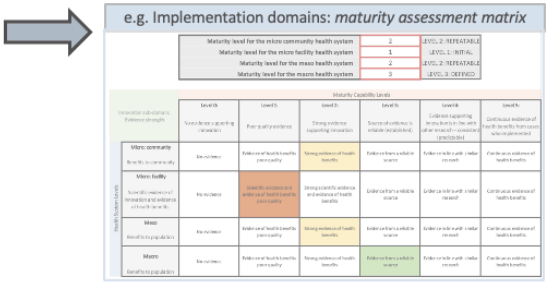
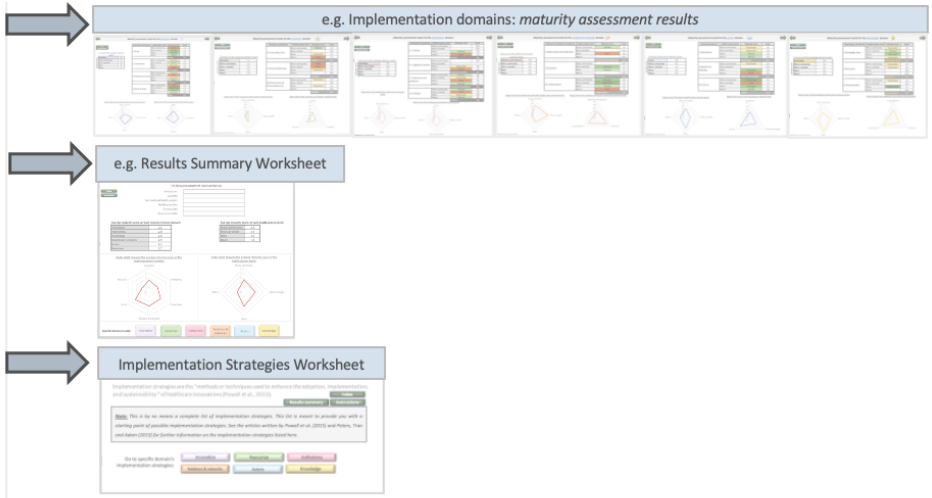


Figure H 4 (cont.): Operationalised HII-MM instructions

iii) Once the *Maturity Assessment* of each implementation sub-domain has been completed, the *Maturity Assessment Result* for the implementation domain is presented.

4. Once the maturity assessments of the six implementation domains have been completed, a *Summary of the Maturity Assessment Results* is presented. The maturity assessment results should be analysed and presented to relevant stakeholders.

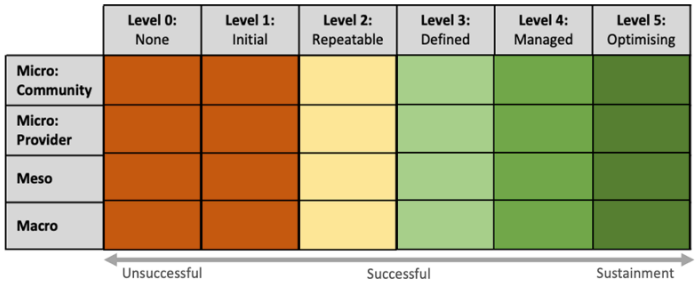
Thereafter, a worksheet listing the potential *Implementation Strategies* for each of the implementation domains is presented. The maturity assessment does not provide specific improvement processes; however, it can be used as a guide to develop an improvement process or to choose an implementation strategy. When choosing an improvement initiative to address an identified gap, the impact and ease of different initiatives, given the available resources, should be evaluated to determine which initiative to prioritise. If you are using the model to benchmark innovations, steps 1 to 4 should be followed for each innovation.



Understanding Maturity Levels

When deciding on a maturity level, it is important to use multiple data sources to reduce the bias that comes with a self-assessment process; there is, however, no correct answer. The maturity levels range from *level 0*, the least optimal level, to *level 5*, the most optimal level of maturity. When assessing a health system level, for it to be at a particular maturity level the characteristics of, the preceding maturity levels have to be met, i.e. *if you identify the micro-community level to be at level 2, the conditions stipulated in levels 0 and 1 must also have been met*. The different health system levels (micro, meso and macro) within a sub-domain do not all have to be at the same maturity level, i.e. *you can have a sub-domain with the micro-community at level 1, micro-provider at level 3, meso at level 2 and macro at level 0*.

The figure below shows that lower maturity levels are associated with lower implementation success rates. In contrast, higher maturity levels are associated with higher implementation success rates and an increased likelihood of sustainability. However, depending on the situation being assessed, different health system levels will have varying levels of influence on the success and sustainability of the innovation implementation process, e.g. *in a particular setting, the micro provider level being at maturity level 1 could lead to an unsuccessful innovation implementation process, whereas the macro level being at maturity level 1 might still allow for a successful implementation process*. Additionally, the different sub-domains will have varying levels of influence on the success and sustainability of the innovation implementation process, e.g. *in a particular setting, low maturity scores for the supporting evidence sub-domain might not have as significant an impact on the success of the innovation implementation process as low maturity scores in the culture sub-domain might have*.



The maturity capability statements describe a pathway for improvement. To improve the maturity score of a sub-domain or health system level, the specific capabilities of the higher maturity levels should be considered, and strategies to achieve these capabilities should be developed. Health system levels and domains do not all have to be at level 3, 4 or 5 for successful, sustainable innovation implementation, e.g. *it might create more value in terms of implementation success to increase the maturity of the design sub-domain to level 4 than increasing the maturity of the policies domain to level 4*. When deciding on an improvement initiative, you should consider the impact that the initiative might have on the success and sustainability of the innovation compared to the resources required for the initiative (cost-benefit analysis).

BEGIN ASSESSMENT

Figure H 4 (cont.): Operationalised HII-MM instructions

H.5 General Considerations Domain User Interface

Figure H-5 shows the general considerations user interface.

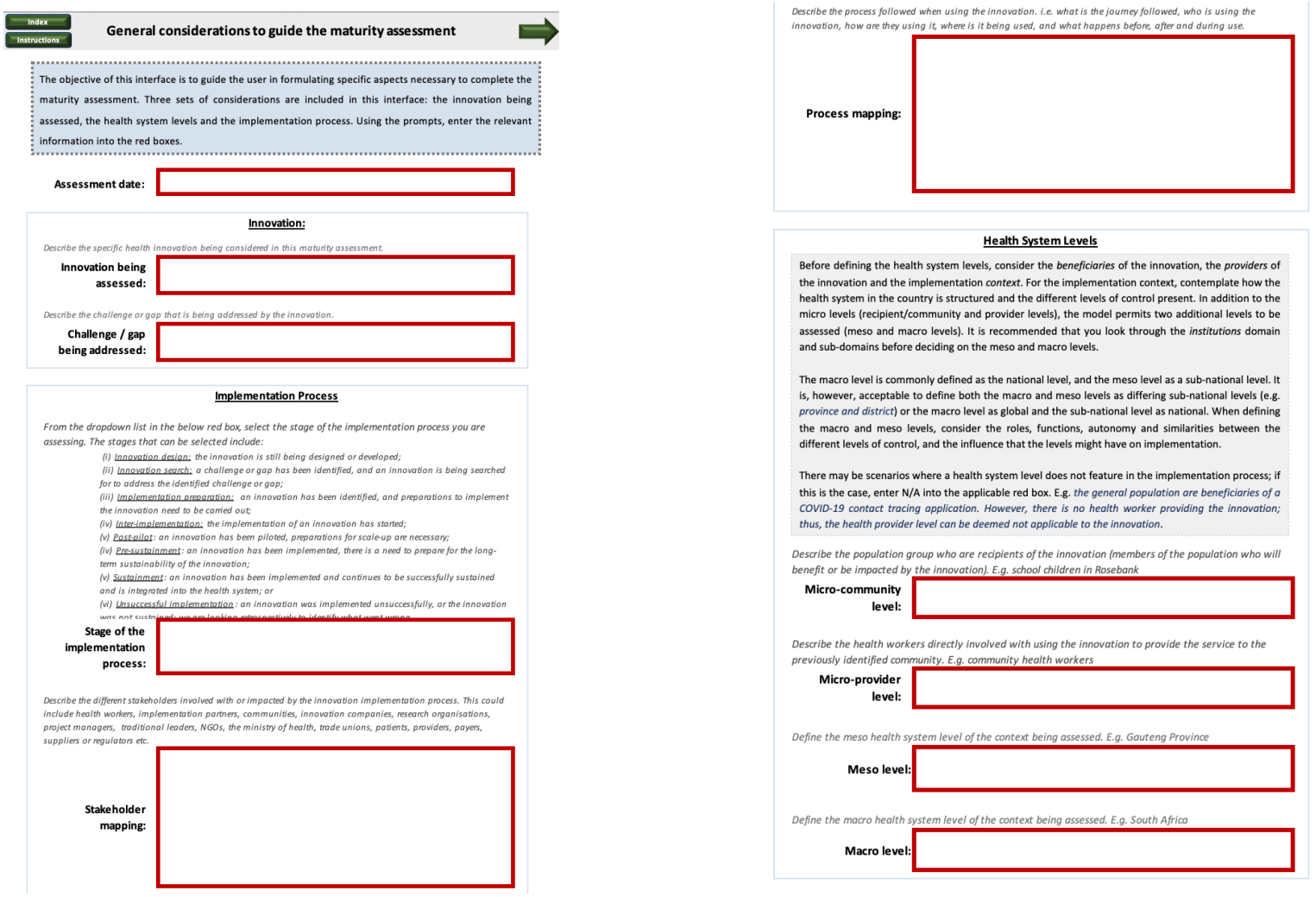


Figure H-5: Operationalised HII-MM general considerations

H.6 Implementation Domain User Interface

The innovation domain user interfaces consist of: (i) a domain overview page, (ii) three sub-domain maturity assessment pages, and (iii) a domain results page. Figure H-6 shows the innovation domain's overview page.

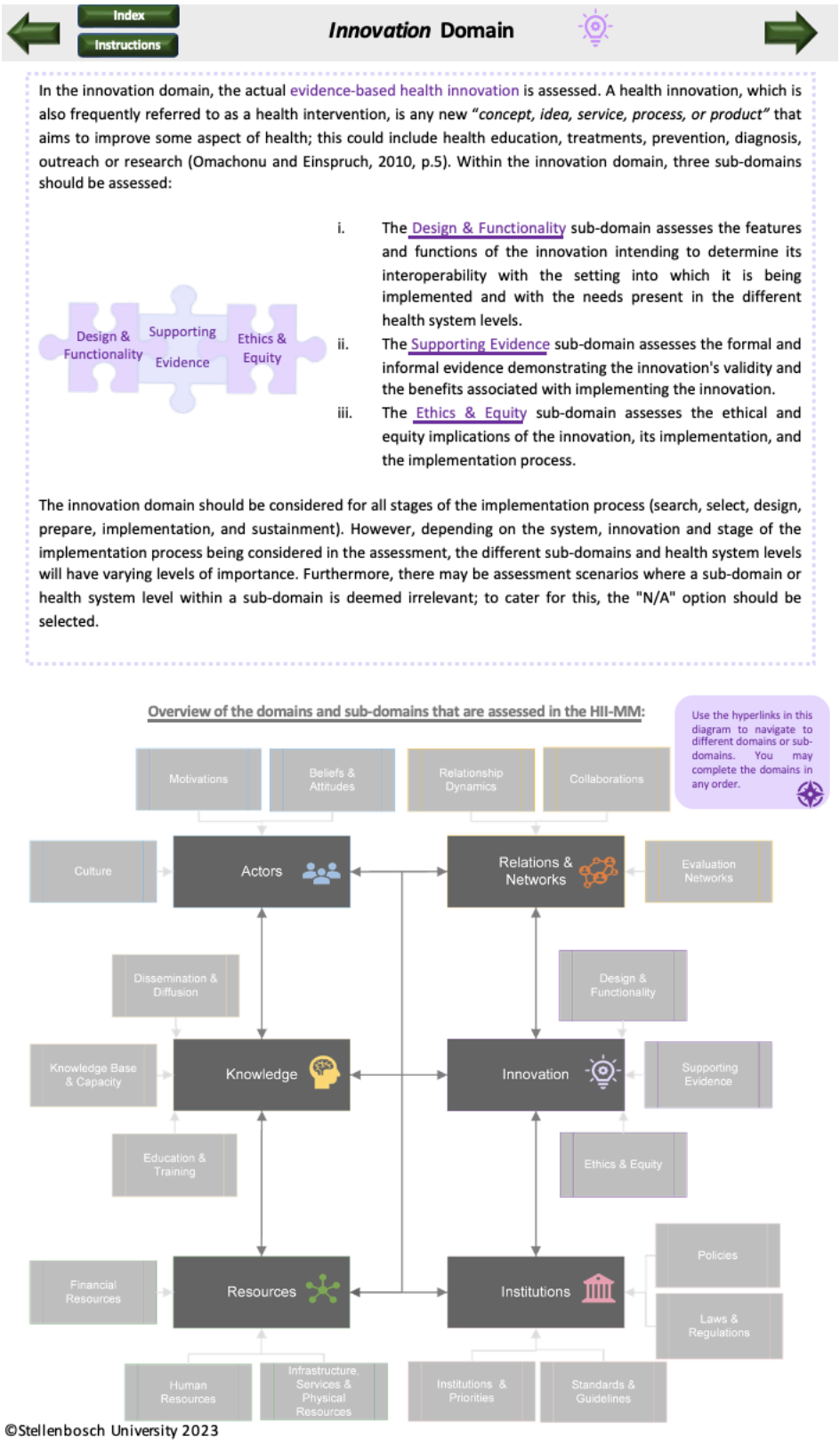


Figure H-6: Operationalised HII-MM innovation overview page

Figure H-7 shows the innovation domain results page.

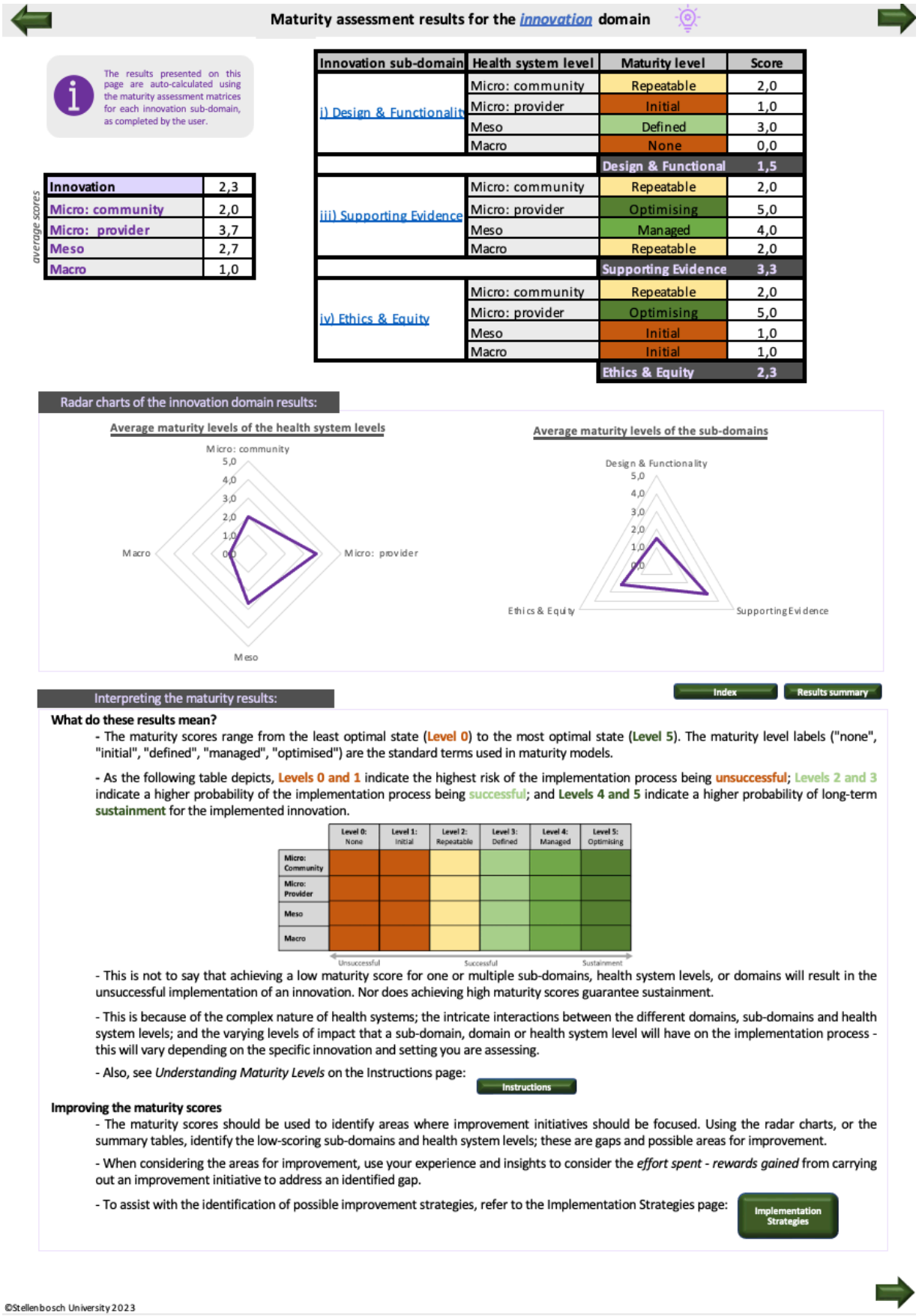
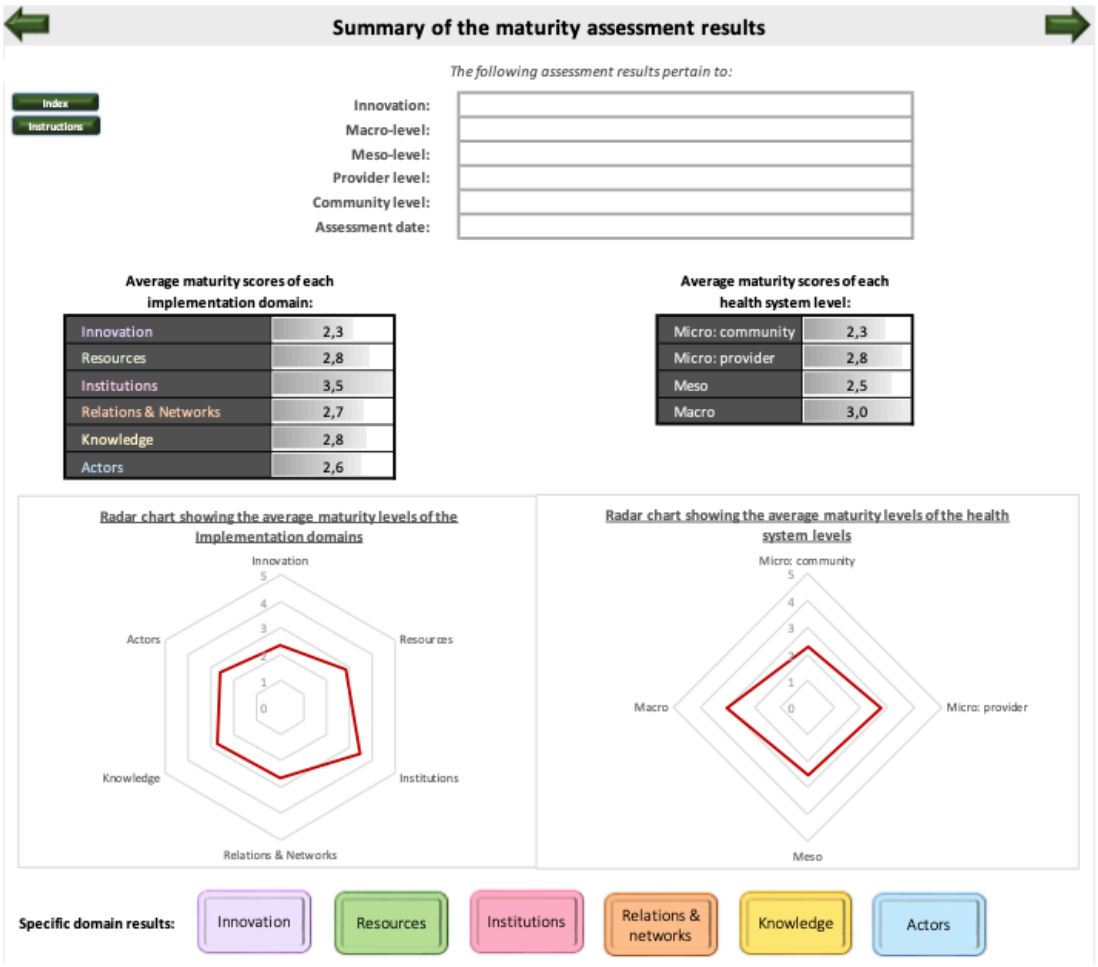


Figure H-7: Operationalised HII-MM innovation results page

H.7 Results Summary

Figure H-8 shows the results summary page of the operationalised HII-MM.



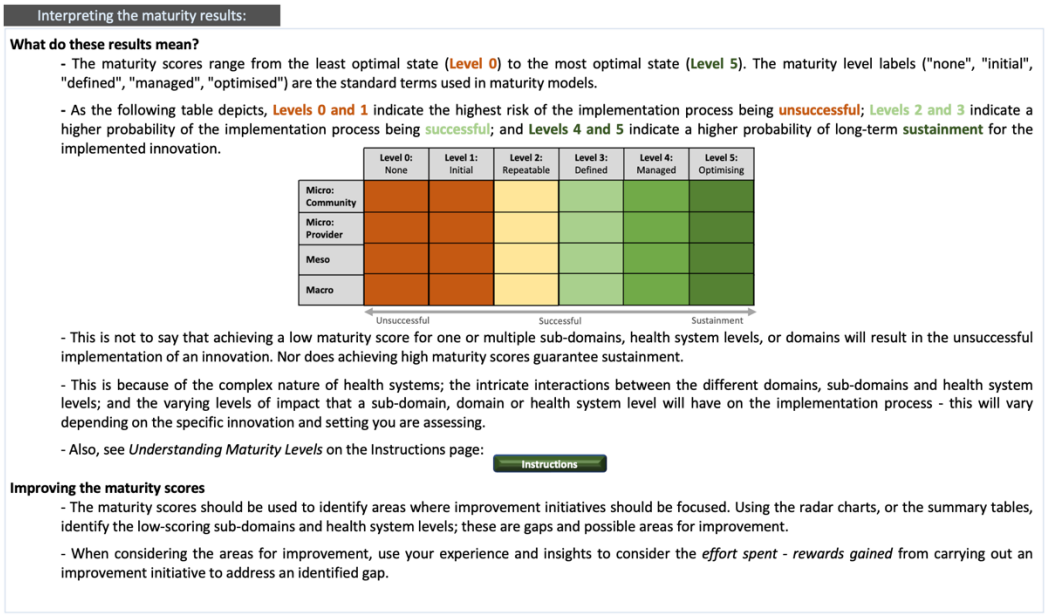
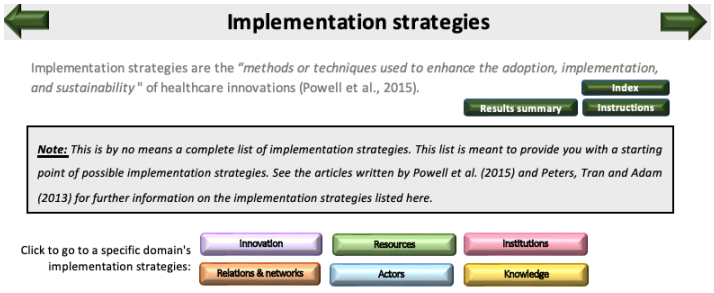


Figure H-8: Operationalised HII-MM results summary

H.8 Implementation Strategies

Figure H-9 shows the implementation strategies categorised according to the implementation domains.



Innovation Domain

Implementation strategy	Source
Conduct cyclical tests of change	(Powell et al., 2015)
Conduct local needs assessment	(Powell et al., 2015)
Involve patients/consumers and family members	(Powell et al., 2015)
Make billing easier	(Powell et al., 2015)
Model and simulate change	(Powell et al., 2015)
Promote adaptability	(Powell et al., 2015)
Purposely reexamine the implementation process	(Powell et al., 2015)
Stage implementation scale-up	(Powell et al., 2015)
Tailor strategies	(Powell et al., 2015)
Strengthen inclusion and participation of the community: community-managed/community-owned services	(Peters, Tran, Adam, 2013)
Assess needs and constraints: develop a constraints reduction plan	(Peters, Tran, Adam, 2013)

Back to top

Institution Domain

Implementation strategy	Source
Policy reviews	(Peters, Tran, Adam, 2013)
Governance strengthening and corruption reduction strategies	(Peters, Tran, Adam, 2013)
Decentralize public service provision	(Peters, Tran, Adam, 2013)
Strengthen local accountability: joint monitoring, provider accountability schemes, or community-based information systems	(Peters, Tran, Adam, 2013)
Change liability laws	(Powell et al., 2015)
Create or change credentialing and/or licensure standards	(Powell et al., 2015)
Develop a formal implementation blueprint	(Powell et al., 2015)
Develop an implementation glossary	(Powell et al., 2015)
Tailor strategies	(Powell et al., 2015)

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Knowledge Domain

Implementation strategy	Source
Public education, behaviour change communication	(Peters, Tran, Adam, 2013)
Quality improvement /quality assurance /performance management strategies: team problem-solving; developing and applying guidelines and standard operating procedures; regular supervision	(Peters, Tran, Adam, 2013)
Marketing health services and products	(Peters, Tran, Adam, 2013)
Continuing education and training	(Peters, Tran, Adam, 2013)
Peer learning and support	(Peters, Tran, Adam, 2013)
Community information and education: training community health workers; training of community members; social marketing and demand creation	(Peters, Tran, Adam, 2013)
Local organisational capacity building: community mobilisation; community boards and structures to oversee and manage	(Peters, Tran, Adam, 2013)
Capture and share local knowledge	(Powell et al., 2015)
Conduct educational meetings	(Powell et al., 2015)
Conduct educational outreach visits	(Powell et al., 2015)
Conduct ongoing training	(Powell et al., 2015)
Create a learning collaborative	(Powell et al., 2015)
Develop educational materials	(Powell et al., 2015)
Distribute educational materials	(Powell et al., 2015)
Make training dynamic	(Powell et al., 2015)
Provide ongoing consultation	(Powell et al., 2015)
Shadow other experts	(Powell et al., 2015)
Tailor strategies	(Powell et al., 2015)
Use data warehousing techniques	(Powell et al., 2015)
Use mass media	(Powell et al., 2015)
Use train-the-trainer strategies	(Powell et al., 2015)
Visit other sites	(Powell et al., 2015)
Work with educational institutions	(Powell et al., 2015)

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Implementation strategy	Source
Audit and provide feedback	(Powell et al., 2015)
Build a coalition	(Powell et al., 2015)
Change accreditation or membership requirements	(Powell et al., 2015)
Change record systems	(Powell et al., 2015)
Create new clinical teams	(Powell et al., 2015)
Develop academic partnerships	(Powell et al., 2015)
Develop and implement tools for quality monitoring	(Powell et al., 2015)
Develop and organise quality monitoring systems	(Powell et al., 2015)
Facilitate the relay of clinical data to providers	(Powell et al., 2015)
Facilitation	(Powell et al., 2015)
Involve executive boards	(Powell et al., 2015)
Mandate change	(Powell et al., 2015)
Obtain and use patients/consumers and family feedback	(Powell et al., 2015)

Figure H-9: Operationalised HII-MM implementation strategies

Relations and networks Domain	Obtain formal commitments	(Powell et al., 2015)
	Organise clinician implementation team meetings	(Powell et al., 2015)
	Promote network weaving	(Powell et al., 2015)
	Provide clinical supervision	(Powell et al., 2015)
	Recruit, designate, and train for leadership	(Powell et al., 2015)
	Remind clinicians	(Powell et al., 2015)
	Tailor strategies	(Powell et al., 2015)
	Use advisory boards and workgroups	(Powell et al., 2015)
	Use an implementation advisor	(Powell et al., 2015)
	Use data experts	(Powell et al., 2015)
	Contracting with performance measures	(Peters, Tran, Adam, 2013)
	Quality improvement/quality assurance/performance management strategies: team problem-solving; developing and applying guidelines and standard operating procedures; regular supervision	(Peters, Tran, Adam, 2013)
	Facility management and logistics systems strengthening	(Peters, Tran, Adam, 2013)
	Strengthen local accountability: joint monitoring; provider accountability schemes; community-based information systems	(Peters, Tran, Adam, 2013)
	Local organisational capacity building: community mobilisation; community boards and structures to oversee and manage	(Peters, Tran, Adam, 2013)
	Obtain broad-based support of stakeholders: engage powerful interest groups; coordinate with community organisations	(Peters, Tran, Adam, 2013)
	Flexible management processes and modification through stakeholder feedback	(Peters, Tran, Adam, 2013)

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	Implementation strategy	Source
Actors Domain	Alter incentive/allowance structures	(Powell et al., 2015)
	Conduct local consensus discussions	(Powell et al., 2015)
	Develop disincentives	(Powell et al., 2015)
	Increase demand	(Powell et al., 2015)
	Intervene with patients/consumers to enhance uptake and adherence	(Powell et al., 2015)
		(Powell et al., 2015)
	Place innovation on the fee for service lists/formularies	(Powell et al., 2015)
	Prepare patients/consumers to be active participants	(Powell et al., 2015)
	Shadow other experts	(Powell et al., 2015)
	Tailor strategies	(Powell et al., 2015)
	Use capitated payments	(Powell et al., 2015)
	Public financing incentives and rules (ways to raise revenues, pool funding, and payment mechanisms)	(Peters, Tran, Adam, 2013)
	Provide financial incentives for teams and individuals based on performance	(Peters, Tran, Adam, 2013)
	Peer learning and support	(Peters, Tran, Adam, 2013)
	Job aids	(Peters, Tran, Adam, 2013)
	Strengthen inclusion and participation: community-managed services; community partnerships and co-management; community-owned services	(Peters, Tran, Adam, 2013)
	Peer support for health services and healthy behaviours	(Peters, Tran, Adam, 2013)
	Assess needs and constraints: constraints reduction plans	(Peters, Tran, Adam, 2013)

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	Implementation strategy	Source
Resources Domain	Decentralize public service provision	(Peters, Tran, Adam, 2013)
	Public financing incentives and rules (ways to raise revenues, pool funding, and payment mechanisms)	(Peters, Tran, Adam, 2013)
	Reorganise and/or integrate services	(Peters, Tran, Adam, 2013)
	Human resource management systems	(Peters, Tran, Adam, 2013)
	Facility management and logistics systems strengthening	(Peters, Tran, Adam, 2013)
	Strengthen financial management	(Peters, Tran, Adam, 2013)
	Financial empowerment: community financing; in-kind subsidies and vouchers; participatory community budgeting; incorporation with income generating and micro-financing schemes	(Peters, Tran, Adam, 2013)
	Access new funding	(Powell et al., 2015)
	Alter incentive/allowance structures	(Powell et al., 2015)
	Alter patient/consumer fees	(Powell et al., 2015)
	Centralise technical assistance	(Powell et al., 2015)
	Change physical structure and equipment	(Powell et al., 2015)
	Change service sites	(Powell et al., 2015)
	Develop resource-sharing agreements	(Powell et al., 2015)
	Identify and prepare champions	(Powell et al., 2015)
	Identify early adopters	(Powell et al., 2015)
	Inform local opinion leaders	(Powell et al., 2015)
	Make billing easier	(Powell et al., 2015)
	Provide local technical assistance	(Powell et al., 2015)
	Provide ongoing consultation	(Powell et al., 2015)
	Revise professional roles	(Powell et al., 2015)
	Tailor strategies	(Powell et al., 2015)
	Use other payment schemes	(Powell et al., 2015)

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Figure H 9 (cont.): Operationalised HII-MM implementation strategies

H.9 References

Figure H-10 shows the list of references directly referred to in the operationalised HII-MM.

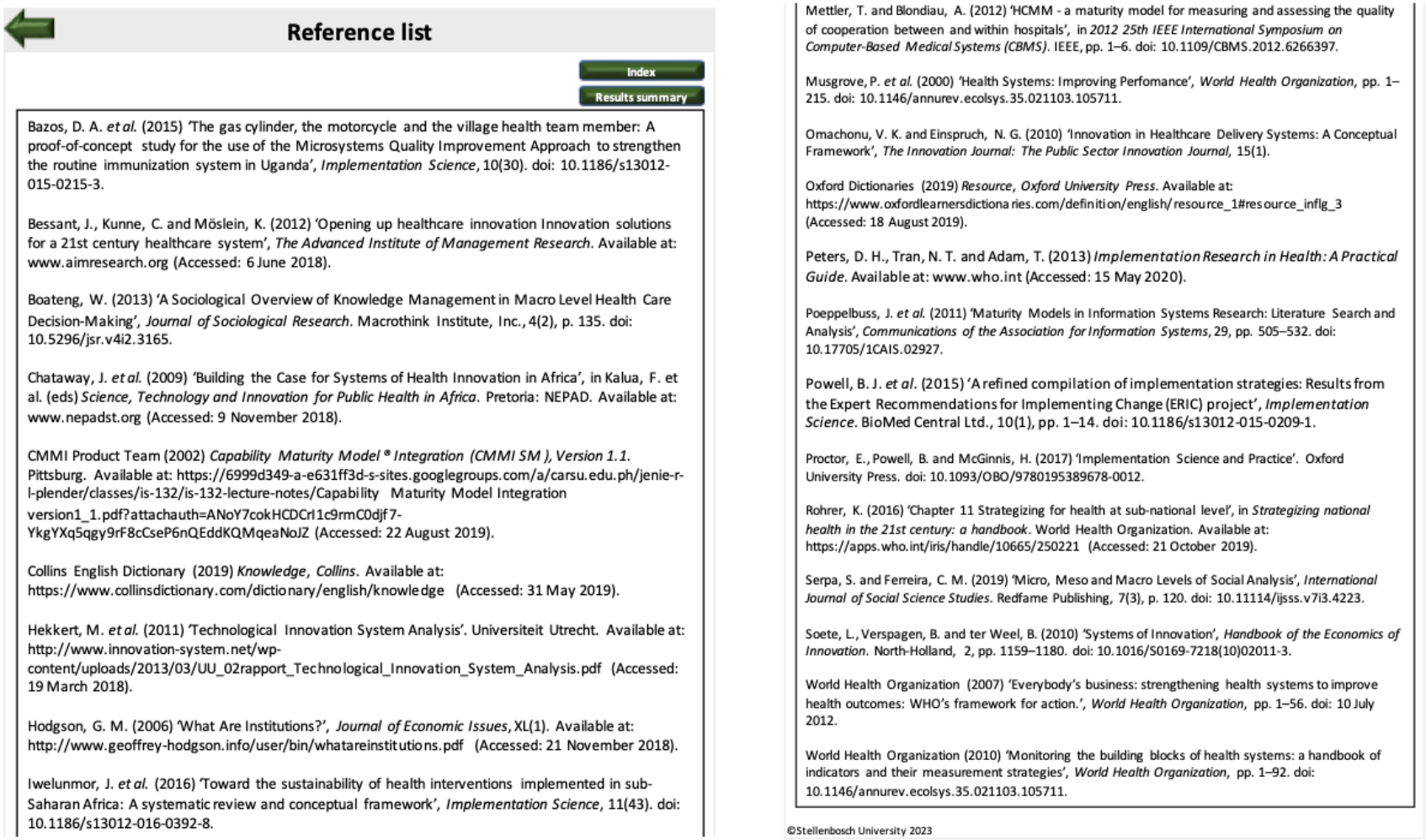

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Figure H-10: Operationalised HII-MM references

Appendix I Subject Matter Expert Interviews Supporting Content

This appendix presents the additional information supporting the SME interviews, as described in Chapter 8 and Chapter 9. Section I.1 shows the presentation and specific questions for the first verification interviews. Section I.2 depicts the presentation for the second set of verification interviews. Section I.3 presents the presentation used to guide the validation interviews. Section I.4 shows the supporting documents sent to the interviewees before the interview. Section I.5 provides an anonymised list (per the REC guidelines) of the SMEs interviewed during the evaluation process. Lastly, Section I.6 provides a detailed discussion of the results of the verification interview. An overview of the three sets of interviews performed during the evaluation process is summarised in Table I-1.

Table I-1: Summary of the interview sets performed during the evaluation process

	First Verification Interviews	Second Verification Interviews	Validation Interviews
Interview date range	20 September 2019 to 4 October 2019	1 July 2020 to 26 February 2021	
# Participants	6	27	
Region(s) covered[23]	Sub-Saharan Africa	Sub-Saharan Africa, Middle East & North Africa; East Asia & Pacific; Latin America & Caribbean; South Asia	
Income levels covered[17]	Low-income; lower-middle-income; upper-middle-income	Low-income; lower-middle-income; upper-middle-income	
Areas of expertise	Innovations; maturity models; health systems; technology systems; mobile health	Healthcare; health innovations; health implementation processes	
Method	In-person and virtual semi-structured interviews	Virtual semi-structured interviews	Virtual semi-structured interviews
Evaluation outcomes	(i) Theoretical verification (ii) Structure verification	(i) Theoretical verification (ii) Structure verification	(i) Relevance: validation of flexibility (ii) Relevance: validation of transferability (iii) Validation of usefulness (iv) Validation of usability
Results	Described in Section 8.2	Described in Section 8.4	Described in Section 9.2

[23] As classified by the World Bank, https://data.worldbank.org/

I.1 Presentation for First Verification Interviews with Subject Matter Experts

Figure I-1 depicts the presentation that was used to guide the first verification interviews carried out with SMEs.

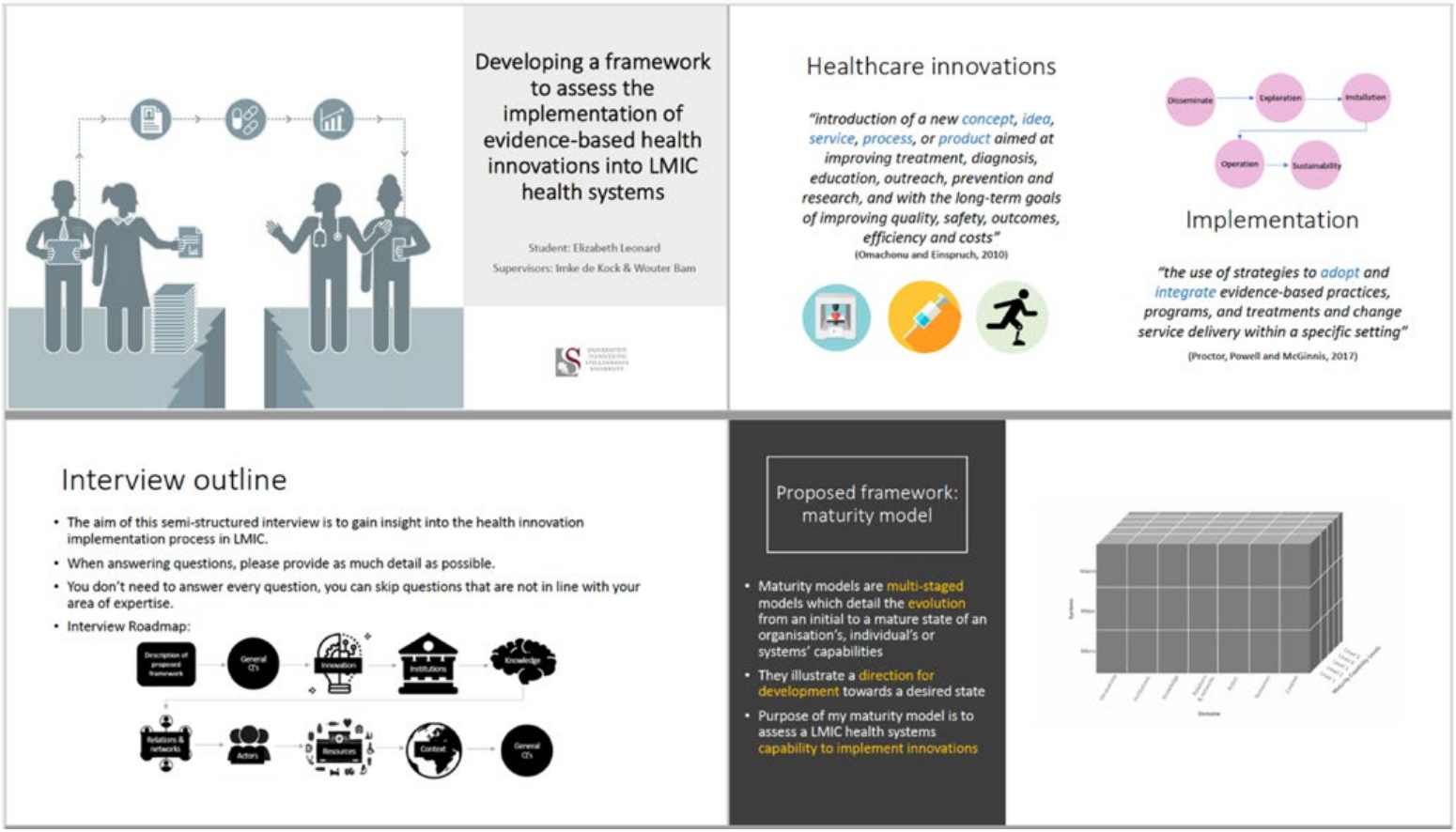


Figure I-1: First verification interviews presentation

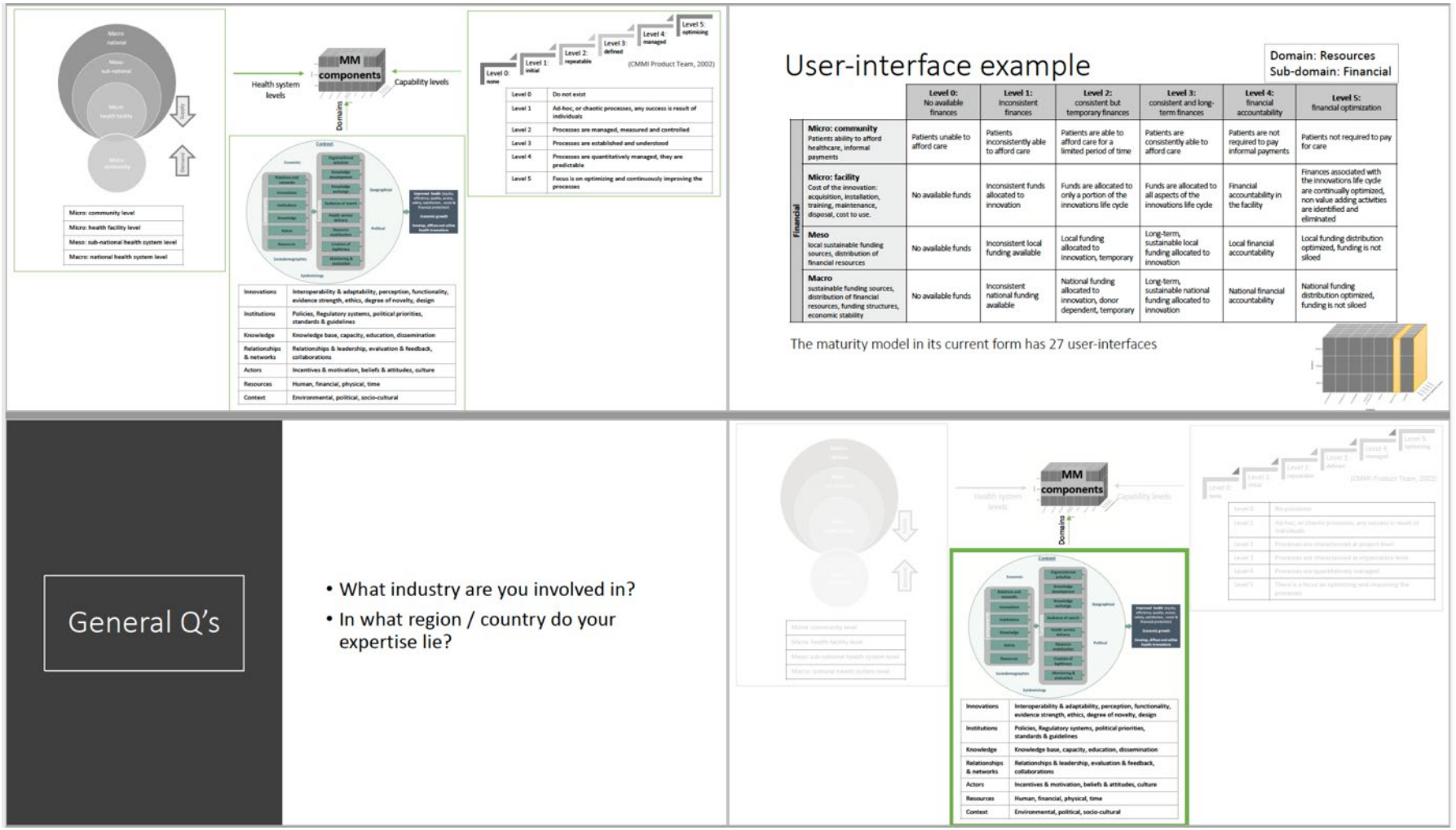


Figure I-1 (cont.): First verification interviews presentation

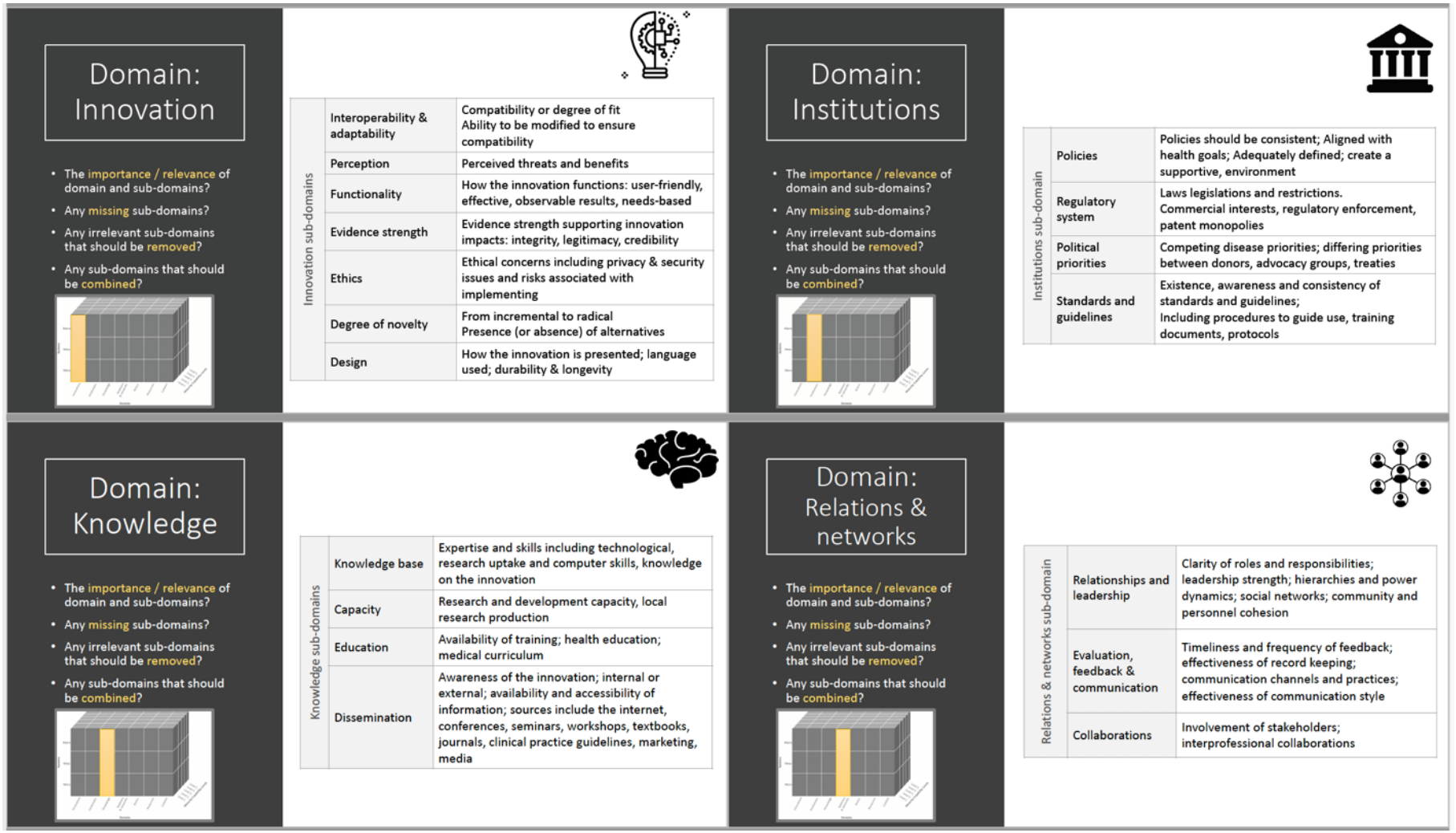


Figure I-1 (cont.): First verification interviews presentation

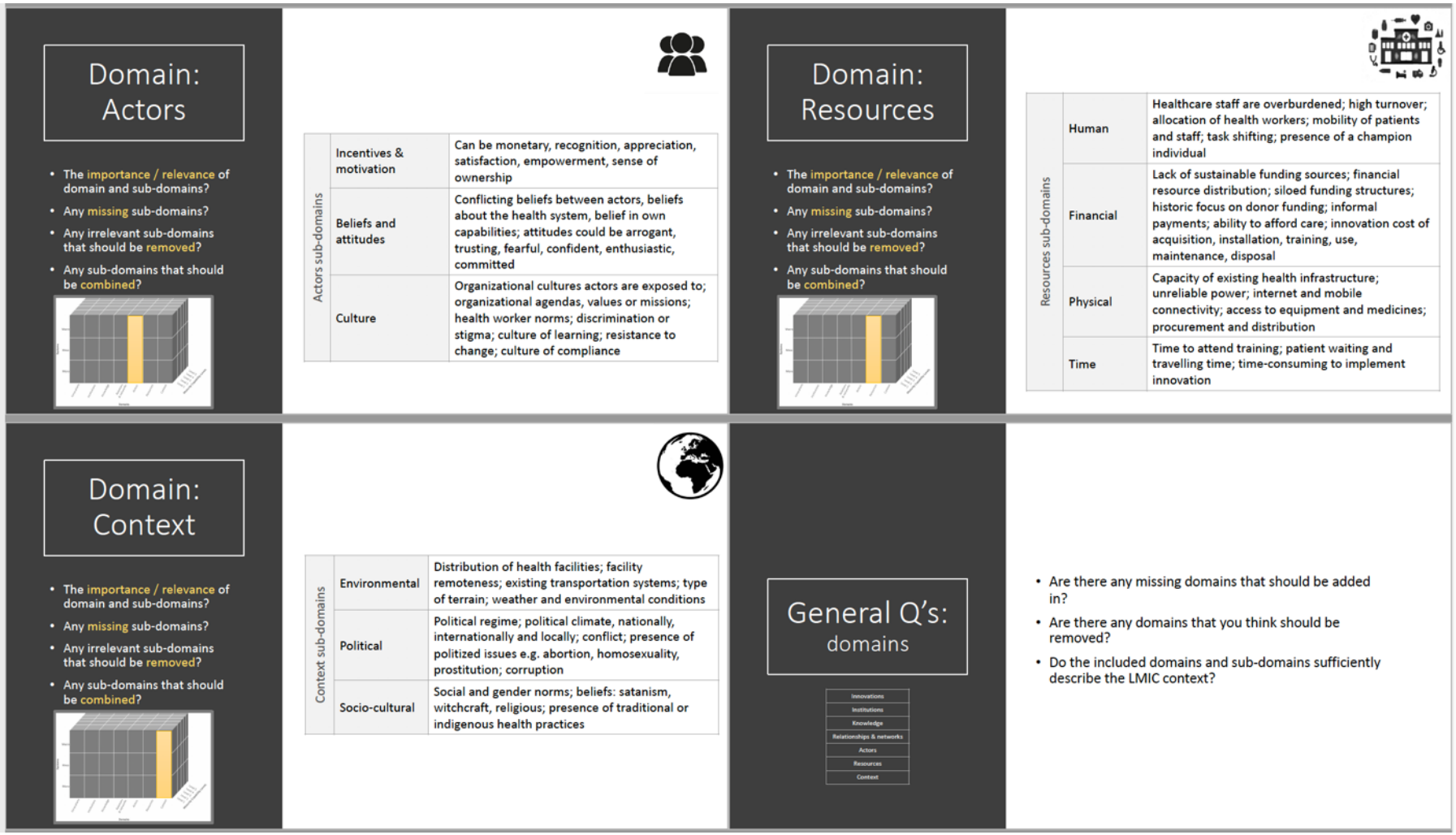
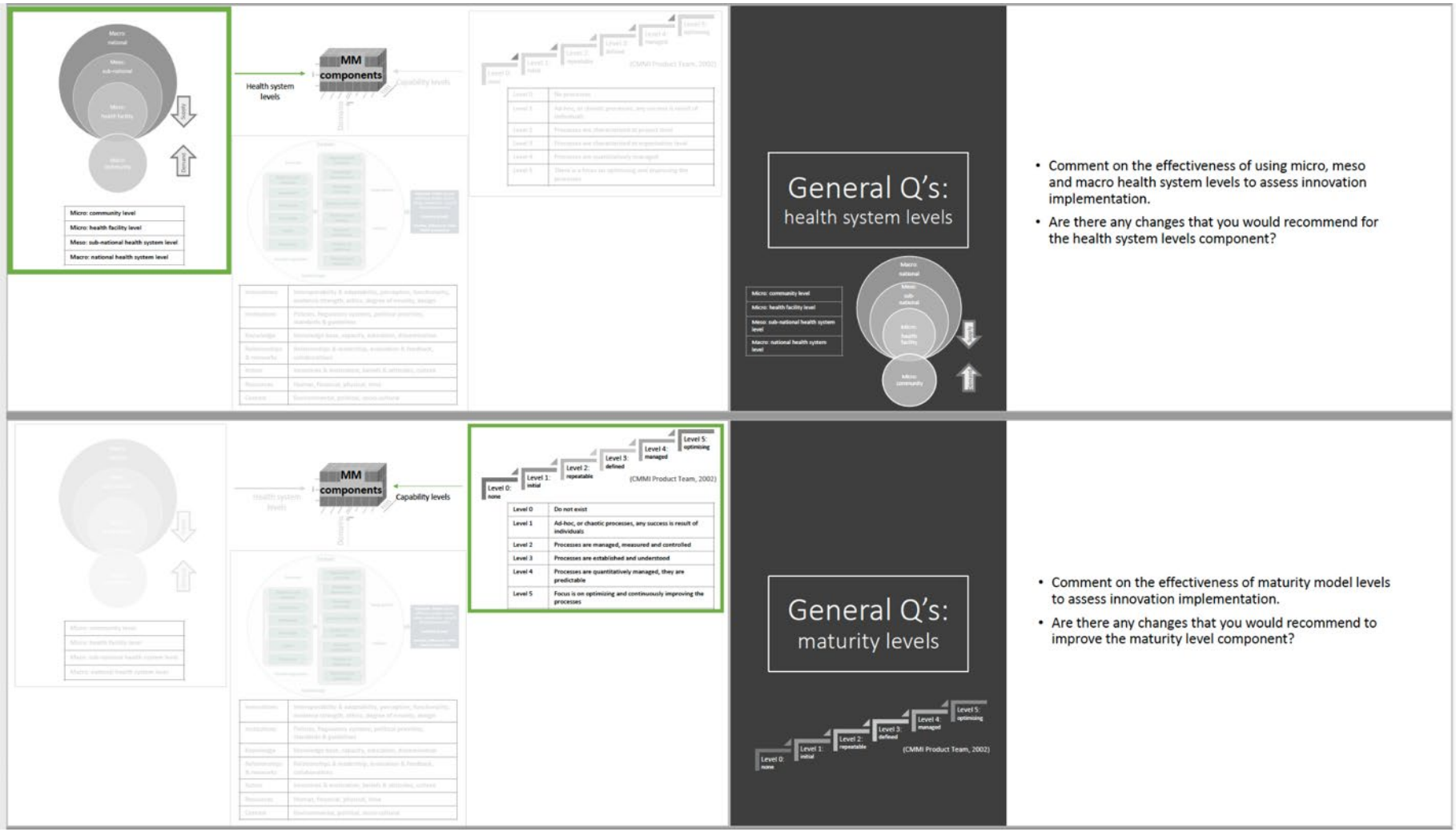


Figure I-1 (cont.): First verification interviews presentation



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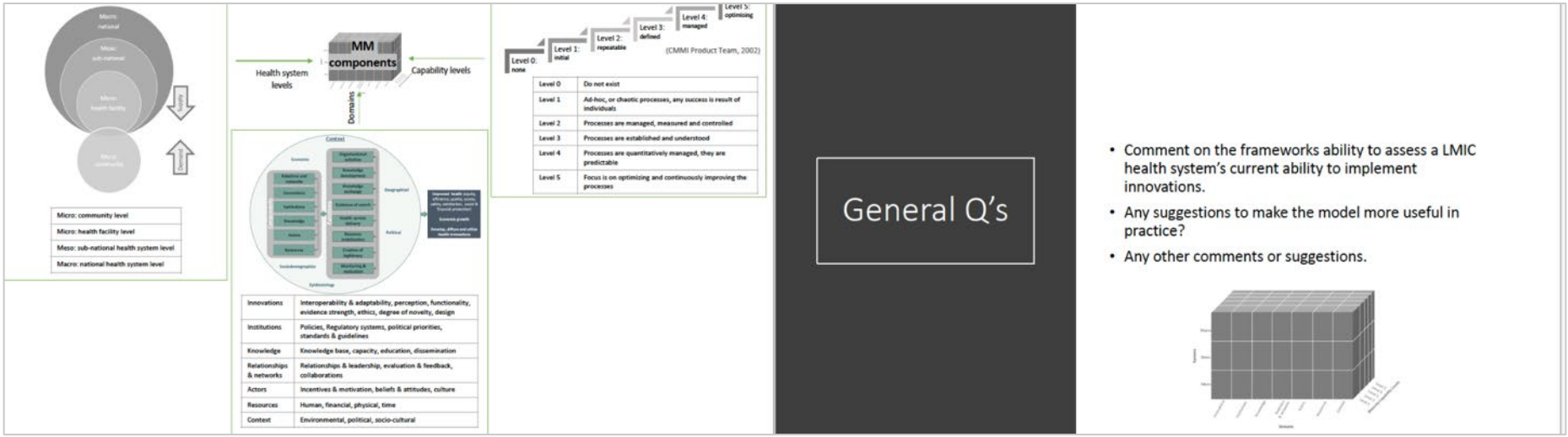

Figure I-1 (cont.): First verification interviews presentation

I.2 Presentation for the Second Verification Interviews with Subject Matter Experts

The presentation was built into the refined maturity model for the second set of verification interviews, enabling the interviewer to discuss each user interface and domain in detail. Figure I-2 depicts the presentation that was used to guide the second verification interviews carried out with SMEs.

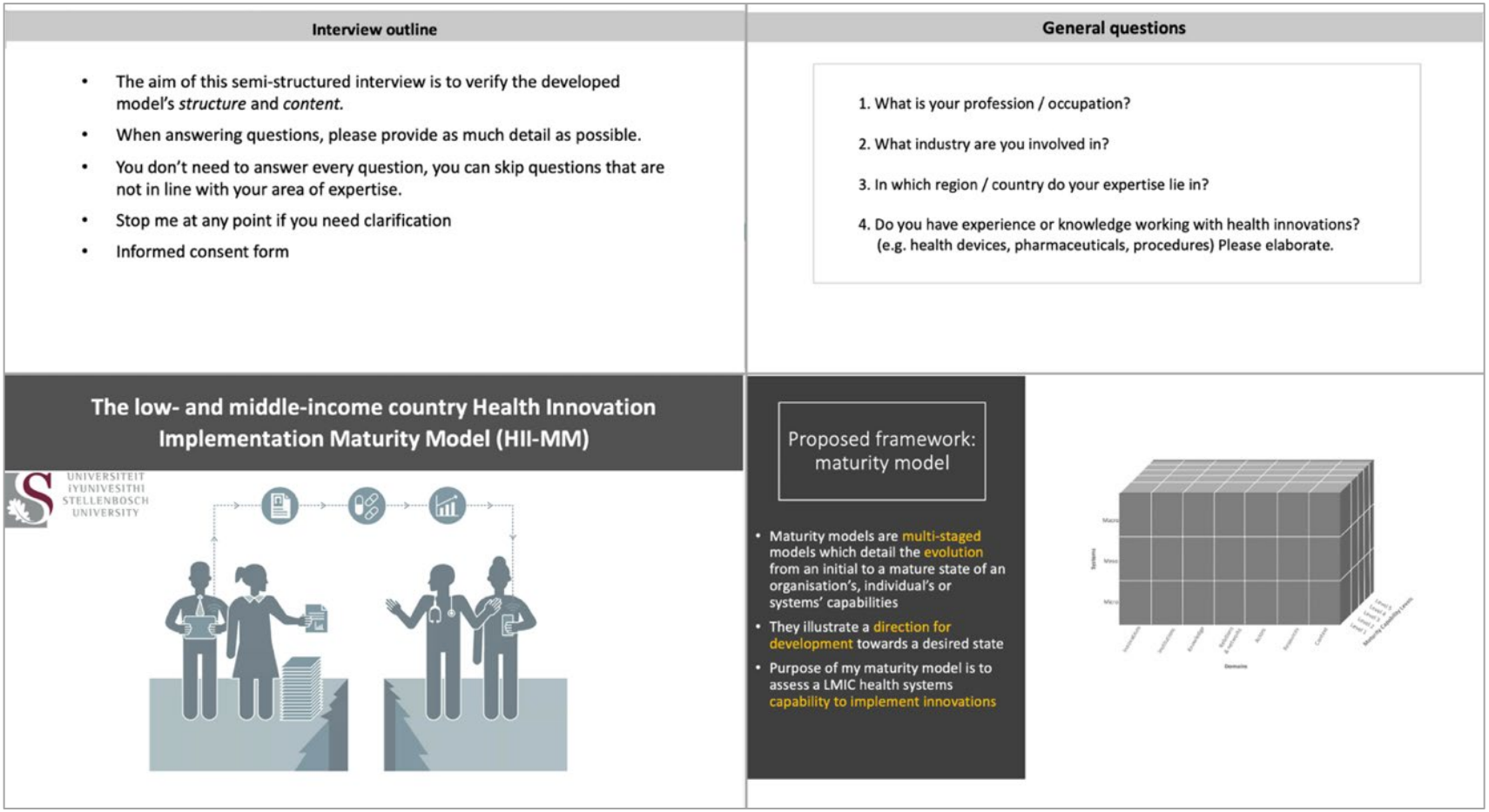

Figure I-2: Second verification interviews presentation

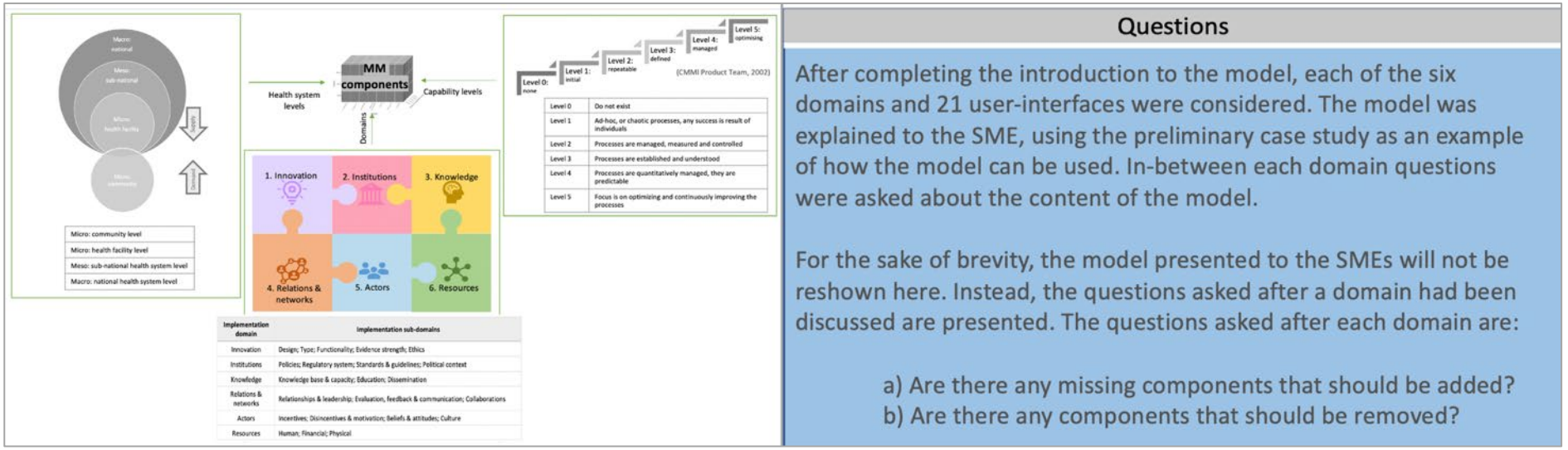

Figure I-2 (cont.): Second verification interviews presentation

I.3 Presentation for Validation Interviews with Subject Matter Experts

For the validation interviews, the interview presentation was built into the refined maturity model, enabling the interviewer to discuss each user interface and domain in detail. Figure I-3 depicts the presentation used to guide the validation interviews with SMEs.

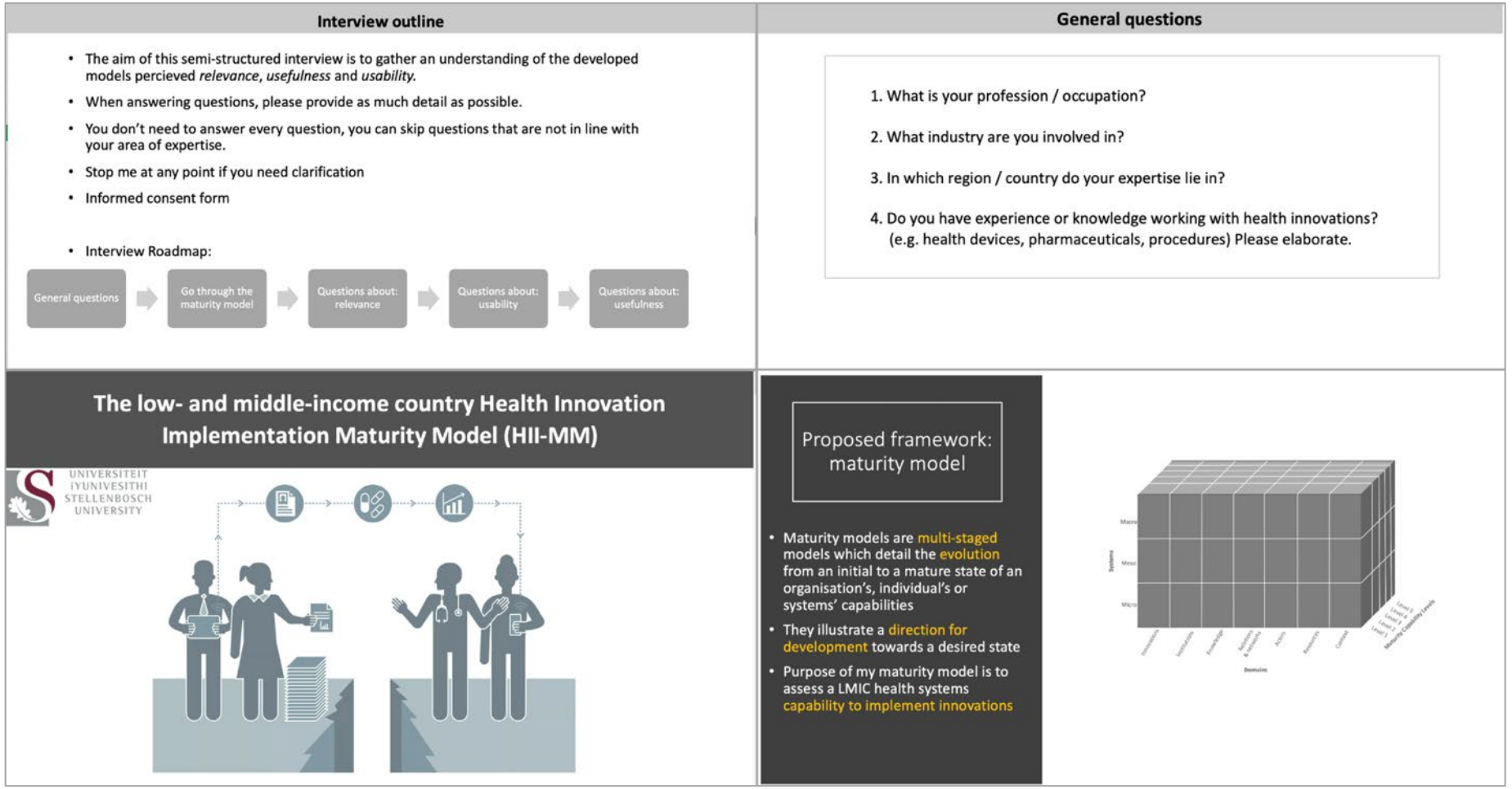

Figure I-3: Validation interview presentation

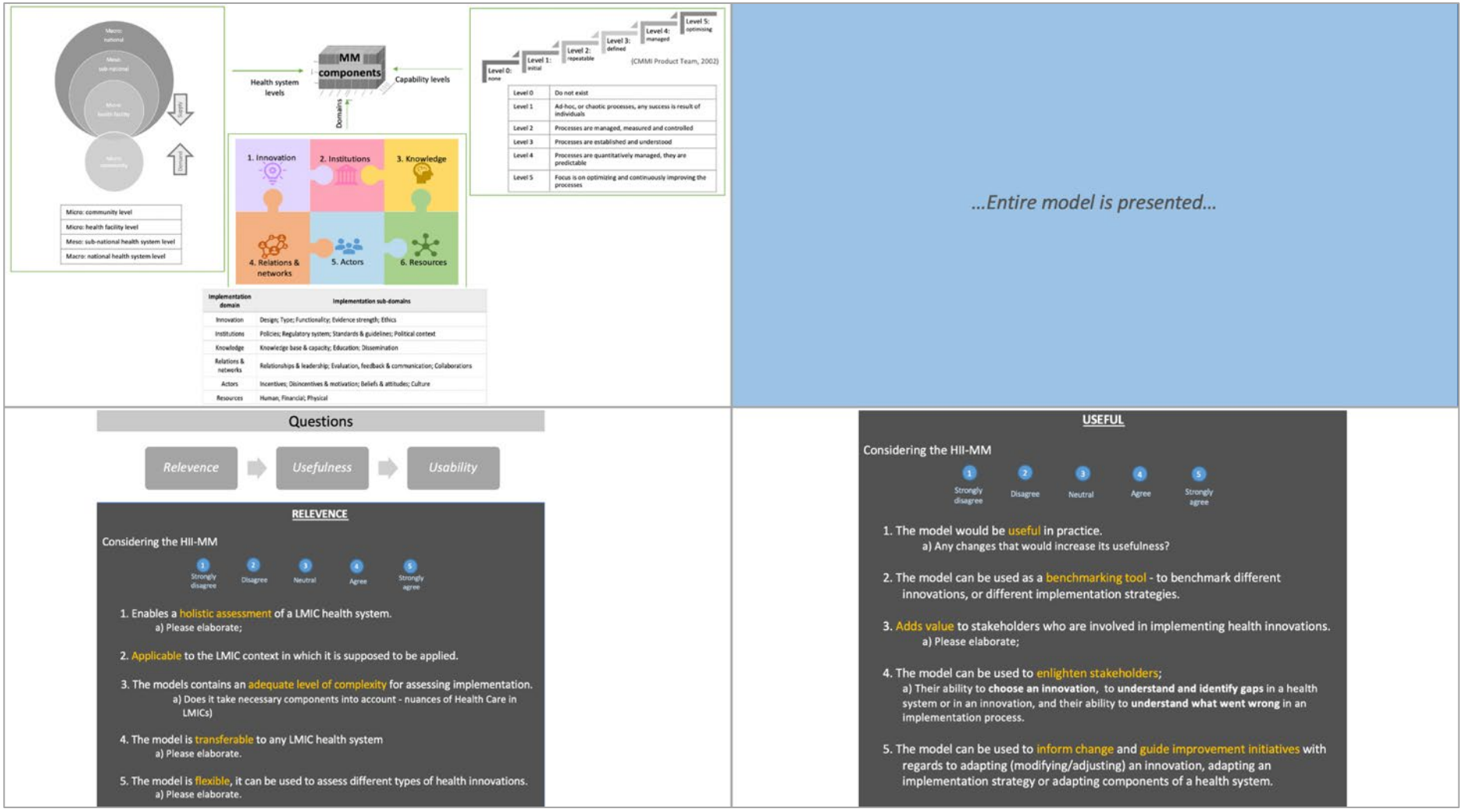

Figure I-3 (cont.): Validation interview presentation

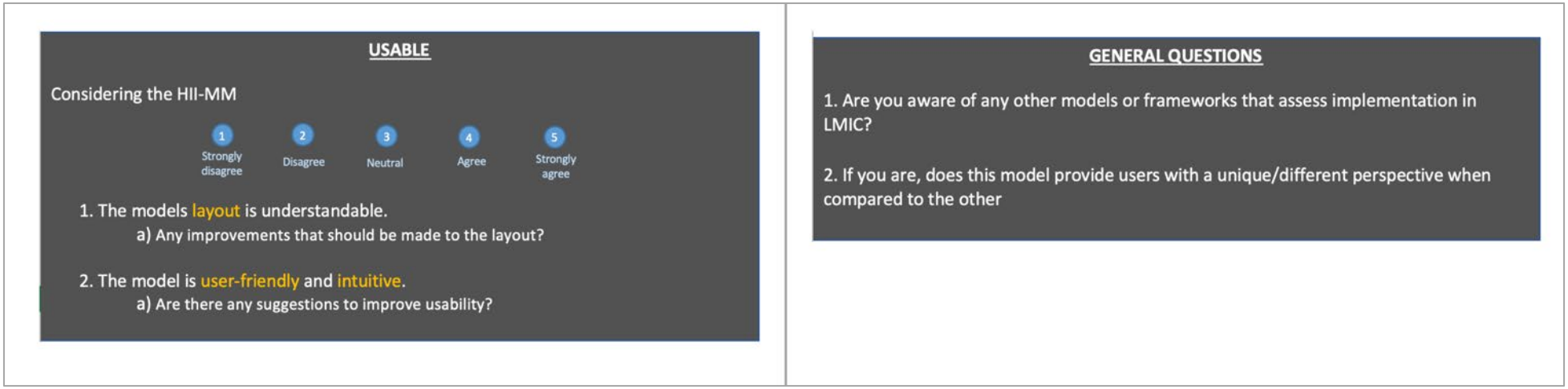

Figure I-3 (cont.): Validation interview presentation

I.4 Supporting Documentation for Interviews

Figure I-4 depicts the supporting document sent to SMEs prior to the evaluation interviews. The document provides the interviewees with basic background information on the study and what to expect during the interviews.

Background information for semi-structured interview

Thank you for agreeing to participate in this study. This document provides an overview of the study and the developed framework. I will describe the framework to you in more detail during the meeting. If you have any questions or require further information, please feel free to contact me (Elizabeth) at 17026946@sun.ac.za or (+27)82 574 4208. You can also contact my supervisors Imke de Kock at imkedk@sun.ac.za or Wouter Bam at wouterb@sun.ac.za.

STUDY:
Evaluating the sustainable implementation of evidence-based innovations in health systems in low- and middle-income countries (LMIC): a maturity model approach.

STUDY BACKGROUND:
Health systems are crucial in improving the health of a country; in order to ensure a health system is well-functioning the implementation of health research and innovations is essential. There are numerous barriers to the implementation of evidence-based innovations into healthcare systems particularly in low- and middle-income countries (LMIC). These barriers result in healthcare stakeholders not receiving potentially life-saving benefits from these innovations.

In order to gain the maximum benefits from evidence-based health innovations, a framework for the sustainable implementation of evidence-based health innovations in the LMIC context are to be developed. The aim of this framework is to increase the sustainable implementation of evidence-based health innovations into LMIC health systems, where and when they are needed.

The purpose of this study is to develop a framework that analyses healthcare innovation systems in low- and middle-income countries (LMIC) with the aim of improving the implementation of evidence-based health innovations (e.g. pharmaceutical, technological, system innovations) into these systems.

INTERVIEW:
As part of this study participants will be invited to partake in a semi-structured interview that will give the principal investigator insights into the barriers and enablers of health innovation implementation in LMIC. The aim of the interview is to receive inputs from various subject matter experts to establish the model's usability, applicability and usefulness.

Here are some example questions:

1. Is the models layout understandable; what improvements could be made?
2. From your experiences is the model relevant to the LMIC context?
3. Are there any missing implementation domains, that you believe are necessary to properly understand a LMIC health systems?

Figure I-4: Background information document for SMEs

OVERVIEW OF THE PROPOSED FRAMEWORK:

The LMIC Health Innovation Implementation Maturity Model (HII-MM)

The HII-MM facilitates the assessment of a LMIC health system, defines the system's current implementation maturity, and provides potential improvement or maturation paths

1. What is a maturity model?

Multi-staged models which detail the evolution from an initial to a mature state of an organisation's, individual's or systems' capabilities. They illustrate a direction for development towards a desired state.

2. What is the HII-MM?

An assessment framework that supports the successful and sustainable implementation of evidence-based health innovations into low- and middle-income countries

3. Who is the model for?

The intended audience of the maturity model can include any health system stakeholders i.e. health system regulators, providers, suppliers, payers and patients. The intended audience will vary depending on the application areas and drivers of conducting the maturity assessment.

4. Are there any costs associated with the model?

There are no direct costs associated with using the model. The indirect costs associated with using the model include employees time and possible travel costs.

5. How do I conduct the maturity assessment?

The maturity model consists of user interfaces which work like marking rubrics. Within the user interfaces each maturity level has a description. A set of guiding questions, are used to determine which description is most applicable to the situation being assessed.

6. What data sources should I use?

Relevant data sources include, but are not limited to, policy documents, population census data, peer reviewed journal articles and interviews with different stakeholders (including the community, health workers, policy makers, project managers, the innovation company etc.).

7. What happens after the assessment?

You can use the results to develop a strategy to address the weak areas that were identified in the innovation, health system or implementation methods. The results obtained from the maturity assessment should be analysed, synthesised and presented to the relevant stakeholders.

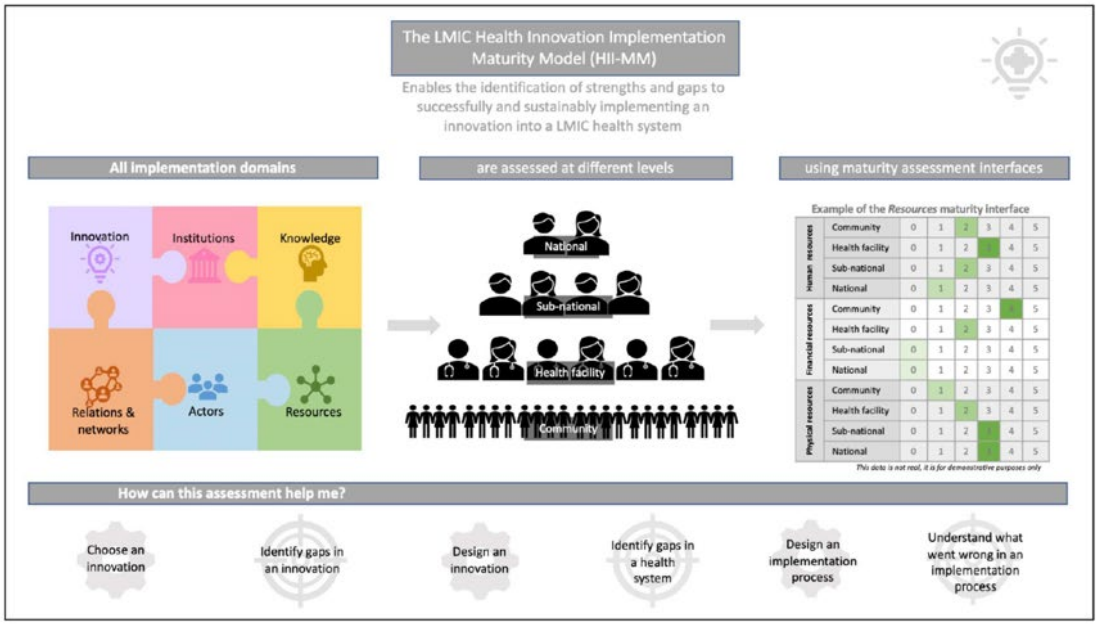

Figure I-4: Background information document for SMEs

DEFINITIONS TO ENABLE A BETTER UNDERSTANDING OF THE DEVELOPED MATURITY MODEL:

HII-MM term	Definition
Implementation	*"the use of strategies to adopt and integrate"* evidence-based health innovations in a specific context (Proctor, Powell and McGinnis, 2017).
Sustainability	Sustainability is the ability to continue over an extended period (Cambridge Learner's Dictionary, 2019), sustainable implementation can be described as the extent to which the innovation is able to continue over time and be assimilated into the specific context (Iwelunmor *et al.*, 2016).
Low- and middle-income country	One method that the World Bank Group uses to classify countries, is through income, which is assessed using gross domestic income per capita (The World Bank, 2019). A country can fall into one of four groups: low-income, lower middle-income, upper middle-income or high-income; countries are re-classified yearly (The World Bank, 2019). Hence, LMIC as used in this study refers to the low- and middle-income countries as classified by the World Bank.
Health system	A health system is defined as "*all the activities whose primary purpose is to promote, restore or maintain health*" (Musgrove *et al.*, 2000), this includes the resources, people, institutions and organisations whose principal aim is to improve health (World Health Organization, 2010).
Micro community health system level	The community level includes the members of the population who are beneficiaries of healthcare services. More specifically, members of the population who are beneficiaries (could be directly or indirectly e.g. family members) of the healthcare services that are a result of the innovation.
Micro health facility health system level	The health facility level refers to the healthcare providers who are tasked with using the innovation. Healthcare providers are not limited to the health professionals within a healthcare facility, healthcare providers include community health workers.
Meso sub-national health system level	The sub-national level is any "*government entity below the national level, regardless of the political, financial and administrative design of the country*" (Rohrer, 2016). The sub-national level includes: parastatals, states (e.g. in Nigeria and India), provinces (e.g. in South Africa), regions (e.g. in Mali and Tanzania), and districts (the local health system) (Rohrer, 2016).
Macro, national health system level	The national level is the first tier of a country's government system (Rohrer, 2016). The decisions made at national level include the planning, delivery, evaluation and regulation of health services (Boateng, 2013).
Maturity model	Maturity models are multi-staged models which detail the evolution from an initial to a mature state of an organisation's, individual's or systems' capabilities (Poeppelbuss *et al.*, 2011) (Mettler and Blondiau, 2012). Maturity models are frequently applied to determine the as-is state of an organisation, they are beneficial in assisting decision makers prioritise improvements (Poeppelbuss *et al.*, 2011). Maturity models illustrate a direction for development towards a desired state (Mettler and Blondiau, 2012).
Innovation	A health innovation is any new "*concept, idea, service, process, or product*" which aims to improve some aspect of health, including health education, treatments, prevention, diagnosis, outreach or research (Omachonu and Einspruch, 2010).
Institutions	Institutions are established as widespread laws, rules or practices that shape social interactions (Hodgson, 2006), they offer structure and insights into how actors behave in the system (Soete, Verspagen and ter Weel, 2010). The roles of institutions are to guide and oversee the health system, and protect the population who use and who are part of the health system (WHO, 2007).
Knowledge	Knowledge is defined as the information and understanding of a subject area (Collins English Dictionary, 2019c).
Relations and networks	Relations describe how things are connected; a network is a group of interconnected people or things. Health innovation networks and relations link groups of actors at national, regional or international level (Chataway *et al.*, 2009).
Actors	Actors are any people who participate in health system actions or processes. Healthcare actors include: patients, providers, payers, suppliers and regulators (Bessant, Kunne and Möslein, 2012). It is the actors in the health innovation system who create, diffuse and use the innovations (Hekkert *et al.*, 2011).
Resources	The supply of something that a country has and can use (Oxford Dictionaries, 2019f).

Figure I-4: Background information document for SMEs

I.5 Subject Matter Experts Interviewed During the Evaluation Process

Table I-2 provides a list of the SMEs interviewed during the evaluation process described in Chapter 8 and Chapter 9. As described in Table I-2, SME1 to SME6 participated during the first verification interviews and SME7 through to SME33 participated in both the second verification interviews and validation interviews.

Table I-2: Interviewees' area and region of expertise

	Expert	Area(s) of expertise	Country of expertise	Region(s)	Country Income Levels
First Verification interviews	SME1	Maturity models and innovation	South Africa / Country agnostic	Sub-Saharan Africa, South	Upper-middle-income
	SME2	Maturity models and innovation	South Africa	Sub-Saharan Africa, South	Upper-middle-income
	SME3	Technology and health systems	Ethiopia	Low-income	Sub-Saharan Africa East
	SME4	Management in the medical industry	South Africa, specifically the Western Cape	Sub-Saharan Africa, South	Upper-middle-income
	SME5	Mobile health, specific focus on medicine availability in primary healthcare clinics	South Africa, Kenya, Zambia, Nigeria	Sub-Saharan Africa: South, East & West	Upper-middle-income; Lower-middle-income
	SME6	Public health, consulting	South Africa, Zambia, Kenya	Sub-Saharan Africa: South & East	Upper-middle-income; Lower-middle-income
Second Verification Interviews AND Validation Interviews	SME7	Public health, implementation research, health innovations, logistics, routine immunisation	Nigeria, Tanzania	Sub-Saharan Africa: East & West	Lower-middle-income
	SME8	Public health, medical sociology and anthropology	South Africa, specifically the Western Cape	Sub-Saharan Africa, South	Upper-middle-income
	SME9	Public health – maternal health and vaccines	Zimbabwe	Sub-Saharan Africa, South	Lower-middle-income
	SME10	Health innovations, eHealth	South Africa	Sub-Saharan Africa, South	Upper-middle-income
	SME11	Social sciences, public health, operational research and biomedical and health informatics	Malawi	Sub-Saharan Africa, South	Low-income
	SME12	Health information systems	South Africa, specifically the Western Cape	Sub-Saharan Africa, South	Upper-middle-income
	SME13	Public health	South Africa, Zimbabwe	Sub-Saharan Africa, South	Upper-middle-income; Lower-middle-income
	SME14	Health services	East Africa (Tanzania, Ethiopia)	Sub-Saharan Africa, East	Lower-middle-income; Low-income

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Expert	Area(s) of expertise	Country of expertise	Region(s)	Country Income Levels
SME15	Public health, implementation science	Zambia, Madagascar	Sub-Saharan Africa: South & East	Lower-middle-income; Low-income
SME16	Public health, global health, health innovations	South Africa	Sub-Saharan Africa, South	Upper-middle-income
SME17	Monitoring & Evaluation, digital epidemiology	Pakistan	South Asia	Lower-middle-income
SME18	Health interventions, gynaecology, health policies	Thailand	Upper-middle-income	East Asia and Pacific
SME19	Child and adolescent mental health research, mental health systems, mental health policies	South Africa	Sub-Saharan Africa, South	Upper-middle-income
SME20	Global health, maternal and newborn health	India, Zambia	South Asia; Sub-Saharan Africa: South	Lower-middle-income
SME21	Health policies, tobacco cessation	China, Vietnam	East Asia and Pacific	Upper-middle-income; Lower-middle-income
SME22	Health education and research, global health	Vietnam, India, Myanmar	East Asia and Pacific; South Asia	Lower-middle-income
SME23	Political economist, sexual and reproductive health	Latin America, Bolivia	Latin America and Caribbean	Lower-middle-income
SME24	Public health	Sudan	Sub-Saharan Africa East	Low-income
SME25	Public health and environmental health	Uganda	Sub-Saharan Africa East	Low-income
SME26	Clinical psychology and global health research	Lebanon	North Africa & Middle East	Upper-middle-income
SME27	Public health and psychiatry	India	South Asia	Lower-middle-income
SME28	Social work and public health	Latin America, Brazil, Columbia	Latin America and Caribbean	Upper-middle-income
SME29	Telehealth, epidemiology, health solutions	Jordan, MENA region (Middle East, North Africa)	North Africa & Middle East	Upper-middle-income
SME30	Health promotion, implementation research	Latin America, Columbia, Mexico, Peru	Latin America and Caribbean	Upper-middle-income
SME31	Physical therapy, health policy	Mexico	Latin America and Caribbean	Upper-middle-income
SME32	Physical therapy, health policy	Mexico	Latin America and Caribbean	Upper-middle-income
SME33	Public health, health systems	Uganda, Kenya, Rwanda	Sub-Saharan Africa East	Low-income; Lower-middle-income

I.6 Verification Interviews Results

The following sub-sections describe the verification interview results for each of the six maturity model implementation domains and the health system levels.

a) Verification Interview Results Innovation Domain

The innovation domain refers to the characteristics of the actual evidence-based innovation being assessed by the model. Each of the four innovation sub-domains (i) design, (ii) functionality, (iii) supporting evidence, (iv) ethics & equity are discussed. In the subsequent sub-sections, insights provided by SMEs on the innovation domain are considered.

(i) Design

Within the design sub-domain, the features of the innovation are considered, specifically concerning the interoperability of the innovation's characteristics with the setting into which it is being implemented. Considering the LMIC context, SME3 discussed the importance of considering the compatibility of an innovation within a specific context "*language is particularly important to consider in Ethiopia where most of the electronic systems are received from western countries in English … so there is a gap in the system and the user's needs. Even with the calendar – in Ethiopia the Gregorian calendar is not used*." SME7 also emphasised the importance of language "*for the language piece using an SMS reminder intervention. I remember during the formative phase when we went to collect the data… we had to translate all the messages in their local language*."

SME3 further discussed the design of the innovation in terms of its interoperability with existing systems, noting that it is "*crucial, especially in the developing country perspective, where there are a lot of different health innovation systems that are introduced by different donors…usually, these systems are gathering similar data and putting too much burden on the end users*". SME4 considered the environmental context, which "*might also influence the readings - equipment needing it be at a stable temperature otherwise readings will differ.*"

SME30 discussed the need to consider the safety of the context that the innovation is being implemented in "*how dangerous the locations in which the intervention is implemented. Like, in our case, we have different primary health care centres participating, and some were just in more dangerous areas,*" which impacted the implementation process. SME27 contemplated the design sub-domain in the context of the interoperability of mental health interventions stating that "*some of these things are more abstract and not so much concrete in terms of the temperature and moisture and things like that. But whether it's…applicable in this culture or not… let's say individualism, so you will have to adapt that for the local culture, because all cultures may not be individualistic, they might be collectivistic*[24]." This links closely to the culture sub-domain in the actors domain.

(ii) Functionality

[24] Individualism attributes personal behaviour to "*personal goals, attitudes*", whereas collectivism attributes personal behaviour to "*goals, attitudes, and values*" of a group (Triandis, 1988, p.60).

Functionality considers how the innovation functions, what it is supposed to do and what it actually does. SMEs frequently discussed the importance of the functionality sub-domain during the interviews. When discussing functionality, SME12 affirmed that they "*agree totally … you first need to say, does the thing do what it's supposed to do? I think that's critical, and sometimes it gets forgotten.*"

The importance of an innovations functionality being needs-based was frequently highlighted, with SME30 asserting that "*it's also my experience … [that] co-creation [is very important]".* SME19 further discussed the importance of functionality discussed the challenge that they, as health promoters, face "*a major problem that we have identified as well, health promoters, is that most of these interventions, we sit down in our offices and then think that this is what the community needs, whereas … what we think they need is actually not what they think they need*."

SME7 stated that they "*liked the fact that the human-centred design process [was incorporated]…from my experience that improves acceptability*" SME7 continued their reflection of a human centred design using an example of an SMS-based intervention that did not successfully meet users' needs, "*[the] community told us was that because of the low literacy level, and most of them cannot read and write, that phone calls, robocalls would be better*".

SME20 provided an additional example of the importance of ensuring innovations are needs-based *"[HIV] prevention as [an intervention] … [for] women in sex work, who in this part of India were really the most at risk…they had a pretty robust community-based program in that setting, and one thing they realised what was really needed rather than introducing a lot of new innovations was just doing, the more simple things in a better way. … and more accessible, … like condoms or other kinds of prevention that…was sufficient to, to prevent HIV, but was … difficult for them … to access … So it's not a, it's not a complex innovation per se, but it was more addressing the context where there was a lot of barriers for, for women to be able to access the things that they actually needed*."

Speaking about an innovation being designed with the community, SME21 discussed the smoke-free house project "*smokers in the public housing, they say, we don't want to be told you cannot move here, or you have to quit. They want to be engaged in the development of campaigns, the message, or even the policy.*" Which is closely linked to the innovation's functionality being designed to meet a need.

(iii) Supporting Evidence

Supporting evidence considers the information supporting the validity of the innovation. From the SMEs that discussed evidence strength in more depth, it is clear that both formal (e.g., peer-reviewed studies) and in-formal evidence (e.g. general observations) should be considered within this sub-domain.

SME24 reflected that LMICs "*[tend to] develop the evidence by practice…there may not be quality, strong evidence, like [publishing in] peer-reviewed journals … but there's a practice [that] can be also a credible evidence if it has a good outcome.*" Similarly, SME16 compared the evidence of innovations developed in HICs compared to those developed in LMICs, "[*the innovation might have] amazing levels of evidence because they were conceptualised in high-income countries and brought*

to low-income countries. Whereas a lot of the frugal[25] *… innovations that [are developed in] low-middle-income countries just don't have the same level of evidence because there's not necessarily the same level of funding…it creates quite an unfair playing field … so holding that as a stringent criteria is important for like evidence-based medicine, but at the same time, [it might] disincentivise further investments into those [LMIC frugal] innovations.*"

SME17 added to the discussion on evidence strength by considering the different stages of an innovation, "*before actually thinking about something, you will have some kind of evidence synthesis when you say, okay, that kind of tool may work. And then when you start developing it, then you have a kind of research and do that prototype testing, where the people will find it useful or not. And then you conduct … viability study. And if you have positive results, then you will further develop.*" In addition to expanding the scope of the evidence strength sub-domain, this observation highlights the importance of defining the innovation stage under consideration.

(iv) Ethics & Equity

The ethics sub-domain considers any ethical implications of the innovation and the implementation process. SME3 stressed that ethics is a "*very critical aspect because of the sensitivity of the data in health systems*".

When discussing ethics, the SMEs had varying perceptions of what ethics should cover. SME8 suggests considering equity within the ethics domain "*sometimes the way that innovations are implemented, they are more easily accessible by certain groups of peoples [not by] others, or … [the innovation] might be intended for everyone, but they don't tend to reach everyone because of, structural factors or maybe some people are being prioritised.*" SME8 further expands by discussing their experience with antiretroviral therapy (ART) "*it's quite simple to put ART in a clinic and say that it's available to everyone, but as it's being implemented, it's not necessarily reaching everyone… [it's important to consider] how an innovation actually reaches the intended recipients.*"

When discussing the innovation domain, SME28 emphasised health equity as a cross-cutting factor: "*I can really see how it will be very useful for my work and some of the programs that I have been a part of; I think that it covers issues of health equity, you know, which is a big topic and important, like under design when you're considering language … then, of course, the ethics, because to me, that's something that I really highlight in my work, so I like that you take that into account*."

SME24 proposed a different perspective on the ethics sub-domain "*to consider the social and cultural security of the community.*" Lastly, SME30 discussed including unintended consequences in the ethics domain, "*unintended consequences, because it's also sometimes kind of related to ethics … the consequences of the projects*."

b) Verification Interviews Results: Resources Domain

The resources domain refers to the assets present within the health innovation system. In the subsequent sub-sections, insights provided by the SMEs on the resources domain are considered.

[25] Frugal innovation uses minimal resources to solve a problem (Tran and Ravaud, 2016).

The three resources sub-domains (i) infrastructure & physical resources, (ii) human resources, (iii) financial resources are discussed.

(i) Infrastructure & Physical Resources

Within the infrastructure & physical resources sub-domain, the existing health system infrastructure and resources are assessed. Physical resources and infrastructure can pose certain barriers to implementation, with SME29 stating that "*the challenges in our region comes from the infrastructure and the unavailability…"* When considering the aspects of physical resources that should be considered during implementation, SME18 discussed the space that might be needed for an innovation, "*we need to provide some space for privacy. So that might need some … innovation of the labour room.*" SME5 gave the example of mobile devices where "*there have been some issues with connectivity which has meant that it's important for the app to be able to function offline.*" SME4 states that the infrastructure costs should be taken into consideration, "*[if] the cost of internet too high, we [should] make sure [data] can be captured offline."* It is clear that the physical resources sub-domain will influence the interoperability of the innovation and should therefore be closely considered with the innovation design sub-domain.

Considering the details of the sub-domain, SME7 expressed that they "*like the fact that you incorporated the maintenance piece because that's one thing that is also [a] problem … in terms of implementing innovations and beyond … [there] should also be the capacity [for maintenance]."*

Discussing the presence of physical resources, SME27 described their experiences, "*medications, they are available at the national level or at the provincial level, but to procure them … someone has to actually do extra effort to ensure that whole process happens - the process of procuring and making that resource available*." It is thus important to consider not only the presence of resources but also the availability of the resources at the different health system levels.

(ii) Human Resources

The human resources sub-domain considers the presence or absence of certain individuals. When reflecting on the implementation individuals described in the model (networker, coordinator, anthropologist, champion), SME8 stated that they "*quite like the idea of having coordinators, networkers and anthropologists because I've only really … learnt of champions when it comes to implementation.*" SME18 contemplated the importance of the presence of champions in the implementation of a maternal health intervention in Thailand hospitals, "*opinion leaders in a participating hospital … are a key person to implement [the] intervention in the respective hospital. So we have to empower them, we have to train them how to run this intervention, how to implement this intervention, how to do audit and feedback.*"

Reflecting on the human resource challenges present during the implementation process, SME11 expressed that "*one of the greatest challenges that we have, from my experience, are the high turnover of staff, and some of the systems have not been able to continue to be supported, and some of them have been abandoned*." This links closely to the knowledge base & capacity sub-domain, which emphasises the need to have sufficient capacity of persons with relevant knowledge, and to the education sub-domain which considers the need for training and retraining.

When discussing the human resources sub-domain, SME5 explored the use of task shifting, which "*can be a good thing, but for some innovations, you have to consider the ethical or privacy issues surrounding task shifting – [if] only [a] certain amount of people have clearance or the password to use the innovation; task shifting becomes a barrier to entry.*" SME19 discussed the benefits of task-shifting in a resource-limited setting "*limited resources is a major barrier, but … there are systems in place to manage the little resources that we have. Take, for instance, using systems such as task sharing…it's possible to train lower cadres, … to deliver some of the services that you would require some specialists to deliver. It would only require supervision, monitoring … creating a feedback system or debriefing sustain. So all those things should also be considered when we say that we do not have resources because if we continue to say we do not have resources… nobody's coming to the party to save us*."

(iii) Financial Resources

Financial resources cover any monetary aspects involved during the implementation process. When discussing the financial sub-domain SME6 considered the role of donor funding, "*donor funding is a big cause of the siloed funding structures because you get money coming from x for a specific purpose, and it has to be spent on that … Siloed funding results in the service delivery being siloed, which then can link with cultural issues.*"

SME17 further discussed the challenges around sustainable financing and donor funding leading to siloed service delivery "*the biggest challenge any innovation would face is finances; and that challenges at two scales, … how to introduce it and secondary, if it is generating results, how to incorporate it within, the larger health care system, because for, both, you need resources… from where you will get the money, that would also determine, which priorities you are going to fulfil. For example, donor's money comes with some agenda*." In addition, SME23 discussed the challenges of "*the national level that does not sustain with funding, sufficient funding for the development of, or maintaining the workers to the level that this is really necessary, or to maintaining the health facilities or the equipment …especially in Bolivia, Ecuador, Nicaragua.*" It is thus important to consider the general health system financing and the financing around the health innovation.

Not all innovations will need a large amount of financial backing, as SME16 discussed "*some health innovations [are] set up to be sort of social entrepreneurship ventures, even within state. You know, there aren't necessarily a hundred per cent reliant on sustainable financing mechanisms or need long-term HR. Sometimes implementation of a innovative procedure may only require [resources for the initial implementation], and then it may be sustained.*"

Discussing sustainability relating to donor funding, SME5 expressed "*what sometimes happens is that there are donors that pay for the first few years, and after that, the government takes over funding if they see value*." SME18 further elaborated on ensuring long-term sustainability of an innovation by engaging the government early on in the process "*during this five-year period, we hope that if this intervention successfully reduce unnecessary c-sections… we can report this to ministry of public health. In fact, we are engaged in them at this stage. We are reporting to them the progress, the purpose of this project, so that, after our project, they will come in to scale up this intervention to other hospitals in Thailand*."

c) Verification Interviews Results: Institutions Domain

The institutions domain refers to the rules, laws and practices that shape interactions within the health innovation landscape. Each of the four institution sub-domains (i) institutions & priorities, (ii) laws & regulations, (iv) policies, (v) standards & guidelines are discussed. In the subsequent sections, insights provided by the SMEs on the institutions domain are considered.

(i) Institutions & Priorities

The Institutions & priorities sub-domain includes the institutions present, the political climate, and the priorities of the health system stakeholders. With many implementation processes in LMICs being funded by donors, several SMEs discussed donor priorities differing from government priorities. SME7 discussed "*trying to … align the innovation with the government priority, to ensure that there's funding to sustain the intervention … you've innovated … donor funding has gone well if your innovation is not within what the government priorities for the health system, it will not be funded*."

SME6 highlighted an additional barrier associated with donor priorities, "*What happens here, specifically with donors who spend millions of dollars on a system, … the donors are very protective of those legacy systems that they spent all the money on, so it makes it very difficult for anything new to enter into the market or into the health system*."

SME9 reflected on donor funding being linked to international priorities; "*differing priorities, between donors … [is] really a big thing … even on an international scale … the international community are dictating that a lot … in Zimbabwe where the ministry of health doesn't have money … going to things like family planning, the donors are completely controlling the family planning in the country*." Further, money from donors tends to be "*earmarked, and it has to be spent on what it's agreed on*."

Contemplating the impact of international priorities have on competing disease priorities, SME23 gave the example of HIV in Bolivia; "*HIV, for example, is a top priority in different countries. Although we don't have that as a main problem, but a lot of money arrives [for HIV], it's a problem of lack of coordination. … there are more children dying of diarrhoea than of HIV… but the government … does not work in collaboration with the different institutions at sub-national levels. That is a problem*."

In addition to international priorities, SME28 suggests considering the priorities of big business, "*for low- and middle-income countries, really highlighting the role that big corporations and economic, private economic interests play on the ability to promote health*."

Reflecting on the political context, SME30 noted that "*political context has been much more relevant on sub-national or facility level, … [with] elections coming up on a national level, [we were tracking] how much impact will that change have on our project. It had some [impact], … We kind of anticipated that the political context would be much more important, like the general national level political context, but ultimately [there was] more [political impact at the] facility level and at regional level that [was] important*."

SME5 added to the discussion of political context and instability in Kenya, "*[we] would get the person in charge of health in the county on board with the innovation, and then the person is fired, and a new person is hired*". Similarly, SME22 reflected on the impact of instability *"a person who was a*

champion for the first couple of months of the rollout of the innovation is now replaced by someone who cares only about making sure he or she is not overspending their budget…I've worked in indigenous communities here, and you have a chief and council who says, yes… let's implement this mental health program. And then… there's a new election and a change in the chief and council, and a new family now is in control, and they don't see the benefits for their extended family."

When considering the political context within a health facility, SME30 noted that "*on the organisational level, because there has been some kind of corruption … that's something that's going [to] delay implementation of the innovation*." When considering the South African political landscape, SME13 described the institutional structure, "*we realised that the reason why it was so difficult in South Africa to implement at times, it was because once you deal with the national level, you still need to deal with the provincial level [to get provincial buy-in].*"

Discussing politicised issues during the implementation of a health promotion intervention in China, SME21 noted that, "*for example, WeChat*[26]*, … some health facilities, they have concern about this, government censorship. So some health organisations, they don't want to collaborate with us on WeChat intervention. So the censorship or … the security assessment is an issue… the study subjects understand there's risks, but … there's issues, for any social media platform … we need to develop a good consent form. … I can only recruit people who are current WeChat users*."

Contemplating the politicised issues component of the sub-domain, SME15 reflected that "*the model wouldn't tell you necessarily don't go ahead. It would just flag that this will be a challenge. So it would score lower just knowing … that the implementer should foresee that they're going to need to do some work in order to address the fact that it's a politicised issue. It wouldn't be to tell the user to avoid politicised issues. It would just be almost a warning that they would need to be prepared ... flag all the areas that might become roadblocks.*"

(ii) Laws & Regulations

Laws & regulations are the mandatory legislation that governs a system. SME23 discussed the challenges with conflicting regulations, "it is seen in different Latin American countries … [it] is a main difficulty, and that there may be conflicting regulations, at different levels at the national sub-national levels that impedes … innovations."

When discussing the regulatory system component, SME17 and SME24 both noted that the sub-national level can have regulatory autonomy. SME17 described the structures in Pakistan "*at the moment in Pakistan, that regulatory system is quite complex. … initially, before devolution, there was a central healthcare system, so that used to look after all the policies around the country, and then in early 2000, there was a constitutional amendment where all these central institutes were devolved into provincial institutes. It means every province will have their own health department, … the central ministry … have a role, but it is still not clear enough … provincial authorities and these central authorities, they keep fighting with each other… they have a regulatory system which worked at the meso-level where you, will have different provinces and they have that authority to develop their own policies, their own procedures*." SME24 discussed the regulatory systems in Sudan

[26] WeChat is a messaging and social media application https://www.wechat.com/.

"*countries having federal governments like United States, … some countries can at the meso-level can have their own regulations. We [Sudan] have a regulatory bodies at the state levels, and sometimes they even contradict with the national level*"

SME22 raised the possibility for regulatory structures to be present at the community level, particularly among indigenous communities, "*in the other countries I've worked in, where you have an ethnic minority group that is exercising sovereignty and land rights and independence, but within the national system, ... I've also done some work in Myanmar and the ethnic minority groups in Myanmar, they actually have treaties with the national government, or they did up until a couple of weeks ago, ceasefire arrangements and things because of open ethnic conflict in the country*."

(iii) Policies

Policies are a group of plans, and ideas agreed on by an organisation. Discussing the need for policies to be to lower levels of the health system, SME11 stated that "*Most of the policies are at a higher level; however, policies do not trickle down, and we know about the importance of having policies at the lowest levels to ensure that people are able to adopt and use an innovation*." SME25 echoed this sentiment "*the presence of [policies] doesn't necessarily equal to the implementation because, in a country like ours in Uganda, we find that you can granted all the boxes in terms of the standards, the policies, the regulatory system, but actually implementation itself [doesn't necessarily happen]*."

To create a more supportive policy environment, SME18 described how they engaged with the government to develop a policy supportive of their innovation; "*About three years ago, I was invited to give a presentation on this issue to the minister of public health, and the administrative team of the ministry of public health and the ministry of public health accept the issue of policy to reduce unnecessary c-sections. So it is, at the national level, a policy of reducing unnecessary c-sections and the hospitals in Thailand have to follow this policy*."

SME26 advised that there are communities that have policies, "*in Lebanon, we have an influx of refugees … they formed their own communities, and then those communities are not always linked to an already established systems and Lebanon. So, because they're not linked, they tend to have their own policies. So, if you want to do data collection, for example, or if you want to introduce a new intervention to these communities, sometimes you might have to go through what's called as a Shawish; a Shawish is like a community leader, independent of the government*."

(iv) Standards & Guidelines

Standards & guidelines include any documentation that guides the use of an innovation or different aspects of the innovation process.

SME30 discussed the impact that standards & guidelines can have on an implementation process compared to policies, "[for the] *alcohol screening … intervention … we have a very different context [in] the three countries. So, for example, in Columbia, there are guidelines that a primary care provider should do that, but that's just like the documents that is there online, and nobody really follows... Whereas in Mexico, they have actually, it's almost like a policy that … [is] instituted … in law that providers have to take alcohol history of a patient. It's like much more like a much stronger institution if you want*."

SME19 described the impact of not having standards & guidelines in place "*in our child and adolescent mental health study, a major barrier to child and adolescent mental health services at the districts …[are] inappropriate referrals… the major reason why … is [that there is] no defined referral pathway. So, we have about three different departments that are actively providing child and adolescent mental health services… the department of health as the major department, and then we have the department of education, and then we have the department of social development… It's important to have guidelines that will speak to all the stakeholders when developing a new innovation, so the roles are clearly defined, and there's a proper procedure that they would follow so that it can achieve the expected result*." This links closely to the collaborations sub-domain within relations & networks, indicating that having the appropriate standards & guidelines in place can facilitate collaborations.

d) Verification Interviews Results: Relations & Networks Domain

The relations & networks domain considers the links between groups of actors within and between different health system levels. Each of the three relations & networks sub-domains (i) relationships & leadership, (ii) collaborations, (iii) evaluation, feedback & communication, are discussed. In the subsequent sections, insights provided by the SMEs on the relations & networks domain are considered.

(i) Relationships & Leadership

The relationships & leadership sub-domain assesses the relationships & leadership structures present within and between the different health system levels. SME6 discussed the importance of relationships & leadership, not only their presence but also implementers needing to understand how the current relationships function, "*often people try implement a certain innovation into an environment they do not understand, and then you cannot foresee the challenges to implementation because you do not know what is happening*". SME30 further emphasised the importance of the sub-domain, stating that in their experience, "*[the] relationships, part is super important, especially in low-income countries where everything's … much more relationship-based … in terms of innovation dissemination. … In high-income countries, it's a bit more technocratic, whereas, at least in our experience in the low- middle-income countries … it's so important to have good [relationships]*."

SME20 discussed relationships and the presence of power dynamics, "*… things like power dynamics … where people are involved from different levels is important because some of those things are so sensitive … they can really make or break whether or not something's going to work*." Thus, being cognisant of the different power dynamics among the different stakeholders is essential.

Considering the community holding health workers accountable, SME7 described their experiences, "*situations where health workers, they don't open the facility to provide services, and nobody is holding them accountable ... And at the end of the month, the government will pay them. But the community [have] been involved with the health workers … holding them accountable to be able to provide services that is due to them*." SME25 also reflected on the accountability element, "*based on our experience, the relevance of leadership has been really clear … when we're introducing an intervention … we realise that those facilities that have a bit more structured leadership … that this whole process goes through …. Without the leadership, without the governance, many of the things actually ended up not working, and that comes along with the element of accountability*."

(ii) Collaborations

The collaborations sub-domain covers any joint endeavour between two or more stakeholders. Collaborations are commonly used as enablers during the implementation process. SME21 discussed the impact that the strained US-China relationships had on international collaborations, "*I have some collaboration project with China, but because the US, China [has] this interesting relationship, international collaboration become very hard…even within the country, if there's no system supporting the cross-organisation collaboration, it will be really hard or be a big challenge for developing mobile health.*" This example shows that the systems supporting collaborations should also be assessed.

SME15 considered how collaborations enable the implementation process, stating that the organisations are "*sometimes it's consulting companies, NGOs, NPOs [non-profit organisation], that are the real drivers and academia actually. … healthcare facilities are … sort of the the necessary partner, but seldom the driver*." Similarly, SME23 contemplated the networks enabling their intervention, "*better nutrition for children and adolescents … it may be the NGO or their research organisation with the community, with the schools where this is implemented [or with] health facilities. And there is a constant feedback of the information of what is being done. And that works perfectly... And also, we experienced inviting a lot of people that might be of the meso-level… But unfortunately, the one that gives the light for sustainability of this projects is at national level. And they are at all, not interested, especially if [the intervention is not being implemented], in the city where the government is placed, they really don't care.*"

SME19 discussed the importance of collaborations in relation to the child and adolescent mental health plan "*you have different departments that are not speaking to each … to manage the power struggle, the power imbalance, the differences that exist in the different programs and different policies that they have… [we set up a] child and adolescent committee. … [with] two strong stakeholders from each of the departments, and then they … meet once a month and then discuss all the issues that need to be discussed. And then they reach an agreement on how to address these issues*." This example shows that collaboration can be an effective strategy to counter the barriers resulting from power struggles.

(iii) Evaluation, Feedback & Communication

This sub-domain covers communication, evaluation and feedback practices within and between different health system levels. Considering the feedback sub-domain, SME3 highlighted that "*getting feedback is important because people are curious*" SME4 added that "*even your challenges must be fed back*".

SME8 discussed the link between evaluation, feedback & communication and successful change management, "*how things are communicated for implementation … I think that has a lot to with how people*

e) Verification Interviews Results: Actors Domain

The actors domain refers to the people participating in the health system's actions or processes. Each of the three actors sub-domain (i) culture, (ii) motivation, incentives & disincentives, (iii) beliefs

& attitudes are discussed. In the subsequent sections, insights provided by the SMEs on the actors domain are considered.

(i) Culture

The culture sub-domain considers the customs, way of life, or social organisation shared between a particular group. SME4 emphasised the importance of the "*cultural competence of the people involved in implementation*". Many SMEs discussed the significant role that culture can play during an implementation process. While discussing the actors domain, SME28 stated that "*it's … really good that you're considering culture, beliefs, attitudes, and you know, a lot of models don't do that, and it's so essential*."

When discussing the gender norms in Sudan, SME24 considered the resistance to being cared for by male midwives, "*In Sudan … there's a [resource] gap between the midwife… [and the] community [they serve], … [even so, the community] will not take our girls or our wives to a male midwife.*"

SME16 discussed the impact of cultural beliefs on treating clubfoot, "*which the Ponseti Method*[27] *addresses … a lot of communities think [clubfoot is] like witchcraft or that [it is] permanent and there's no way to correct it. There was resistance to putting on the Plaster of Paris even though it's an amazing innovation; it's saved so many children from unnecessary surgery.*"

When reflecting on the impact of culture on implementing innovations, SME13 discussed the introduction of male medical circumcision, "*South Africa is very strong in traditional male circumcision*[28]*. So, it was so difficult in two provinces that are traditionally circumcising. … [in] the Eastern Cape, I remember for the longest time, young boys have been dying because of [traditional] methods used. So, when the new devices came, the new innovations to medical male circumcision, there has been so much resistance…if you have been circumcised using a device and everyone else has been cut by … a blade... It speaks less of the whole process*."

Contemplating culture within an organisation, SME16 discussed the influence that culture in healthcare facilities can have on implementation "*the culture of a healthcare facility sometimes trumps, say, individual's beliefs & attitudes or cultures in the sense of some hospitals … [there is] an amazing learning culture*." Thus, the culture in an organisation might be more influential than the cultures of the individuals within the organisation. SME17 also considered the influence of culture within an organisation "*whether they are receptive towards change or whether they have resistance towards change… these are all those things which are actually hidden. What people say [doesn't] necessarily reflect what they believe…if you see their record historically, so for example, in last ten years, how many new innovations … they have adopted, … or they have taken to the scale, through their own resources, through their own will and through their own wish.*"

(ii) Motivation, Incentives & Disincentives

[27] The Ponseti method is a technique used to correct clubfoot using a plaster cast to correct the position of the foot (Dietz and Noonan, 2016)

[28] Traditional male circumcision is practised largely within the Xhosa population group throughout South Africa as part of a rite of passage to manhood (Meissner and Buso, 2007).

In the *motivation, incentives & disincentives* sub-domain, the actors motivations are assessed in terms of the explicit and indirect incentives and disincentives. SME27 highlighted the importance of this sub-domain "*I would say that I'm extremely happy that you were brought in this particular sub-domain … I haven't seen many models which have very explicitly put focus on motivations*."

When discussing motivations among health workers, SME25 stated that in Uganda, "*most of our systems nowadays [have moved] towards a results-based financing*[29] *[model] … such motivation systems can actually influence implementational innovations*." SME9 also discussed the results-based financing model, which is also present in Zimbabwe "*the monetary thing you touched on is a very, very real thing. Within the maternal health, it's been noted that … results-based funding, … [can lead to] moms [being] referred a bit late because they want to manage the case and they realised they can't …and the woman … dies on route [during the transfer]*." There are ethical implications that should be considered when different incentives are being investigated, specifically with regard to unintended consequences; SME4 discussed that, "[the] *choice of incentives is a very important thing to consider on a cultural and ethical basis.*"

Multiple different kinds of incentives and disincentives can influence the implementation process. SME5 described being able to "*prove that the innovation gives value*" can act as an incentive. SME18 discussed how they are using value-add as a motivation for their innovation, "*if we can implement [the intervention] effectively, it will result in less unnecessary c-sections, less complication to both the mother and the babies in short term and long term. And we will spend less money because the infection is more expensive [to treat] … we believe that is the incentive at the national [level] … at the population or community level, if we can explain the, the benefit [of natural birth] and risk of [c-section] infection … they will benefit from this, [they] will spend less money. They will have less complications*. "

When discussing possible disincentives, SME13 considered providing services free of charge leading to unintended consequences, where people "*don't put value in the things that we receive in some cases, because it's for free.*" SME8 discussed motivations being linked to targets, "*targets can act as incentives and unfortunately do act as incentives, and things that aren't target-based often get deprioritised … [if] there's not an external drive or oversight, then often, things will not be taken up*."

There is certainly a need to understand motivations and to incorporate incentives into the implementation process; SME19 states that "*It's very important that you provide incentives for your target population, whether it be community members, whether they're health workers, it's one thing that would motivate them to do their part. So it's very important to provide incentives*." SME3 gave the example of "*healthcare professionals, especially those who considered the system as a burden of extra work, say that they must be incentivised.*"

(iii) Beliefs & Attitudes

The beliefs & attitudes sub-domain considers actors' beliefs have, which then influence their attitudes.

[29] Results-based financing is a model of funding where "*the principal, who provides the funding, pays the agent, who implements the project or provides the service, upon achieving predefined results*" (Grittner, 2013, p5)

When discussing the mHealth intervention that SME7 was involved with implementing, SME7 recalled that "*when it was designed, the design was originally for it to be on the ankle. In the community, they felt it was strange because, … people felt like it's like a handcuff, … they recommended that … it be one on the wrists, so that is more like you watch*." Understanding stigmas or motifs that an innovation might be associated with is important. SME19 discussed the beliefs & attitudes surrounding mental health interventions, "*many beliefs and perceptions of mental health conditions [exist]; many people would believe that mental health disorders are linked to spirituality or things like that.*"

Speaking to preconceived beliefs about health facilities, SME23 described, "*most of the time when [patients] arrive, [the facility] is closed because the health facility has [no staff], for example … the doctor or the nurse are queuing up for their salary. Luckily that has changed in the last years. But, well, these preconceptions come from something that they believe that these are bad quality and if they would have some money, they would go to a private consultation… those are the real barriers.*" In addition to the preconceptions about health facilities, SME8 discussed beliefs in terms of trust, "*there is this issue of trust, and I think … do the recipients trust the health system? Do they trust the health workers that they have their best interests at heart? Again, that also has to do with knowledge and education … the idea is to what extent do recipients trust in innovation?*"

SME3 considered methods that they have used to manage the beliefs & attitudes of actors; methods include the "*huge mobilisation to communicate about the benefits of the system to the end users … so they can realise that if they implement this system, it will benefit them*". Managing beliefs & attitudes are linked to motivating actors to use an innovation.

f) Verification Interviews Results: Knowledge Domain

The knowledge domain refers to the information and understanding actors have of the various aspects of the implementation process. The three knowledge sub-domains (i) knowledge base & capacity, (ii) education, (iii) dissemination & diffusion, are discussed. In the subsequent sections, insights provided by the SMEs on the knowledge domain are considered.

(i) Knowledge Base & Capacity

The knowledge base comprises the expertise and skills a person has, and knowledge capacity considers the number of people in an organisation or system with the necessary knowledge base to use or implement the innovation. The high level of staff turnover was frequently discussed by SMEs when considering capacity.

SME19 highlighted that "*you cannot just assume that they [the community] have the, the right level of information, or they have the right level of literacy … you have to first measure the level of knowledge and… decide if it's met up with… whatever level that you expect*."

SME17 emphasised the importance of understanding the knowledge base of the people who will use the innovation, *"if people for whom we are trying to develop that innovation, if they are not skilled, then the whole purpose of doing that exercise or developing that innovation, that goes in vain, which will be very unfortunate*."

SME3 provided an example of the knowledge base sub-domain hindering the use of an innovation, "*in terms of computer skills, doctors not wanting to use the innovation system because they have slow typing skills and don't want to be embarrassed in front of patients. The skill and knowledge of innovations, especially within the older generation, are also a very critical one*".

When considering the knowledge base surrounding c-sections, SME18 discussed the knowledge base of the community, "*Many of them consider the c-section to be easy, to be convenient and not causing problem. So, the knowledge base about …the c-section among women is not enough. So that's why we want to provide them the knowledge about this*." Assessing the existing knowledge base enables the implementer to establish what type of educational intervention should be used to improve the success of the innovation.

Discussing high staff turnover and the implications on the knowledge capacity in Nigeria, SME7 highlighted the "… *need to … build capacity of program managers, like government program managers. So those employed by government…[are] able to take up this innovation even after [initial human resources] do not exist.*"

SME8 reflected on the impact of high levels of staff turnover during the implementation of an ARV electronic treatment register "*continuity of…. [and] the ownership and the accountability of, people, maintaining the data, [meant that the data quality was] compromised*." Thus, high levels of staff turnover can impact the sustainability of the innovation

SME9 discussed one of the interventions being used in Zimbabwe to ensure a sustained knowledge base "*they've adopted the principle of on-the-job training. So, they've stopped sort of these larger, [trainings]. What they do is they'll just pick a select few … [who] are responsible for going back to the facilities and training everyone else. That's quite to do with that high turnover that you can't have training sessions every month because every month is like a whole different group. So, it just keeps core people trained, and then they [are] responsible for [cascading] training*."

(ii) Education

Education includes any process that facilitates learning; this includes training for the innovation, the medical curriculum in the country and health education in a country. SME3 notes that "*education is one of the main shortfalls in Africa … education needs to integrate the IT or innovation curriculum into the existing medical curriculum*."

Reflecting on the education domain, SME30 described "*from our experience, this education, especially … previous education of the providers, … makes a big difference in how fast they, are willing to, integrate innovation… [there is also a] connection between the policy and guidelines and existing knowledge in a way, … Mexico has some policy that's … more conducive to our intervention, which meant that providers also had more knowledge already*."

SME19 highlighted that when educational or training materials are being designed to support the implementation process, establish what method "*… would be the most suitable for that target population*." Although this is not directly linked to designing the innovation, ensuring that the training material is interoperable with the target population corresponds with the innovation design sub-domain.

Referring to the education sub-domain, SME4 noted that "*what shows to be effective is peer education.*" In addition to peer training, SMEs noted the importance of retraining or having sustained engagements. SME25 noted that "*in some of the innovations and work that we'll do, we'll feel like it's really important to have refresher trainings, more frequently because of attrition but also …sometimes [healthcare workers] get taken up into other things and, the relevance of continuing to do that [training], becomes key.*" Which links closely to high levels of staff turnover, as discussed in the capacity sub-domain.

SME33 discussed the need for retraining while noting the possibility of time constraints, "*when we … implemented one of our projects, there was a need to try and retrain rebuild capacity, but there was also a time constraint to it*."

Considering sustained education, SME27 highlighted that "*beyond capacity building or beyond training and beyond providing, the initial training you need to have that sustained engagement and, working together to improve the healthcare provider performance…in terms of behaviour change.*" This links to the culture sub-domain in which change management is considered.

(iii) Dissemination & Diffusion

The dissemination & diffusion sub-domain encompasses the active and passive spread of information to increase the awareness of the innovation.

SME3 emphasised the importance of the dissemination sub-domain "*it's a problem area in most innovations," SME3 went on to discuss an example of healthcare actors who "have been collecting a lot of data, but the analysis and dissemination part is very poor, and even the data that is analysed are not disseminated to the decision makers or other stakeholders*."

When discussing HIV self-testing, SME13 considered reasons why people were not testing; this included the spread of misinformation about HIV-status "*those beliefs as well … [as] lack of information can also hinder the use of some of these [innovations].*"

Considering the dissemination of misinformation, SME23 considered the impact of social media, "*I think the challenges is growing because of … social media [that] is accessible, and every moment you're being bombarded with information.*"

SME18 described their efforts to disseminate accurate information to improve the knowledge base of the community, "*I have been interviewed by one of the newspapers… here in Thailand… I think social media is another important factor for the success of this intervention*."

SME26 described the limited dissemination practised by some organisations, "*sometimes they tend to prioritise, disseminating their findings to their donors and very rarely does their work go out to the public or to other people that can use it. So as opposed to academics, for example, who ended up publishing their work [in] scientific journals and also that's rarely translated to the public*." These reflections emphasise the need for appropriate dissemination strategies to expand the knowledge capacity further. Which links to SME20's contemplations on information equity, "*access to information, within a community of people who may be, more or less privileged … it cross cuts with sustainability, but because if it's only impacting or helping those who really have more access to information or education, then it will leave … other people [behind]*."

g) Verification Interviews Results: Health System Levels

When considering the health system levels, SME1 stated that "*looking at any system in aggregate or disaggregate forms is critical – you do need to be thinking about levels*." SME2 continued to discuss the importance of considering all of the health system levels to ensure sustainable implementation, describing that "*it's important to consider all the different levels because all of these levels need to be integrated to ensure sustainable implementation*."

SME3 considered the health system levels from an equity perspective, stating that "*these are important to ensure that the country as a whole benefit from the innovation. An example is the multiple donor-funded projects present that do not talk to each other because of a lack of macro-level regulations and policies. It is very important in ensuring the interoperability of the systems … If you don't have micro-level success, how would you bring about the macro-level success*."

SME5 also discussed the importance of considering health system levels, "*It is necessary to have these different levels because it differs greatly depending on what you are looking at. It is important to note that even if you are only looking at the micro-level, it is likely that you will pull through to look at the meso- and macro-level. Any innovation that you want to see at the macro-level, you would have to collect data from a micro-level. It wouldn't make sense to look at them separately, but it does make sense to look at them individually*."

When discussing the health system levels, SME8 considered the structure of the model and the importance of the community level, "*I like your use of, almost like an ecological model where… the community is very important to include … it's actually one of the areas that people often aren't so considerate of when it comes to innovation … if you're implementing something … it's important really to understand how that innovation will be taken up in a specific community and to understand the structures that you need to engage with in order to… promote a favourable environment… which is the same at a facility level, same at national and all the other levels*."

SME20 considered the relationships between the different levels, "*considering that there's those different [levels] macro- all the way to micro-. I thought that was really helpful because some of them might be more or less related… including the community there … sometimes that's more or less important, or you're more able to kind of assess that.*"

Appendix J Case Studies Supporting Content

This appendix presents the additional information supporting the case studies performed during the evaluation phase of this study. The case studies are described in Chapter 8 and Chapter 9. Section J.1 comprises the questions used for the interview undertaken as part of the verification case study. Section J.2 details the results of the verification case study. Lastly, Section J.3 presents the information supporting the COVID Alert validation case study.

J.1 Verification Case Study Questions: mHealth Audiology Device

Figure J-1 shows the presentation used to guide the case study interview held with the project manager who was involved with implementing the mHealth audiology device.

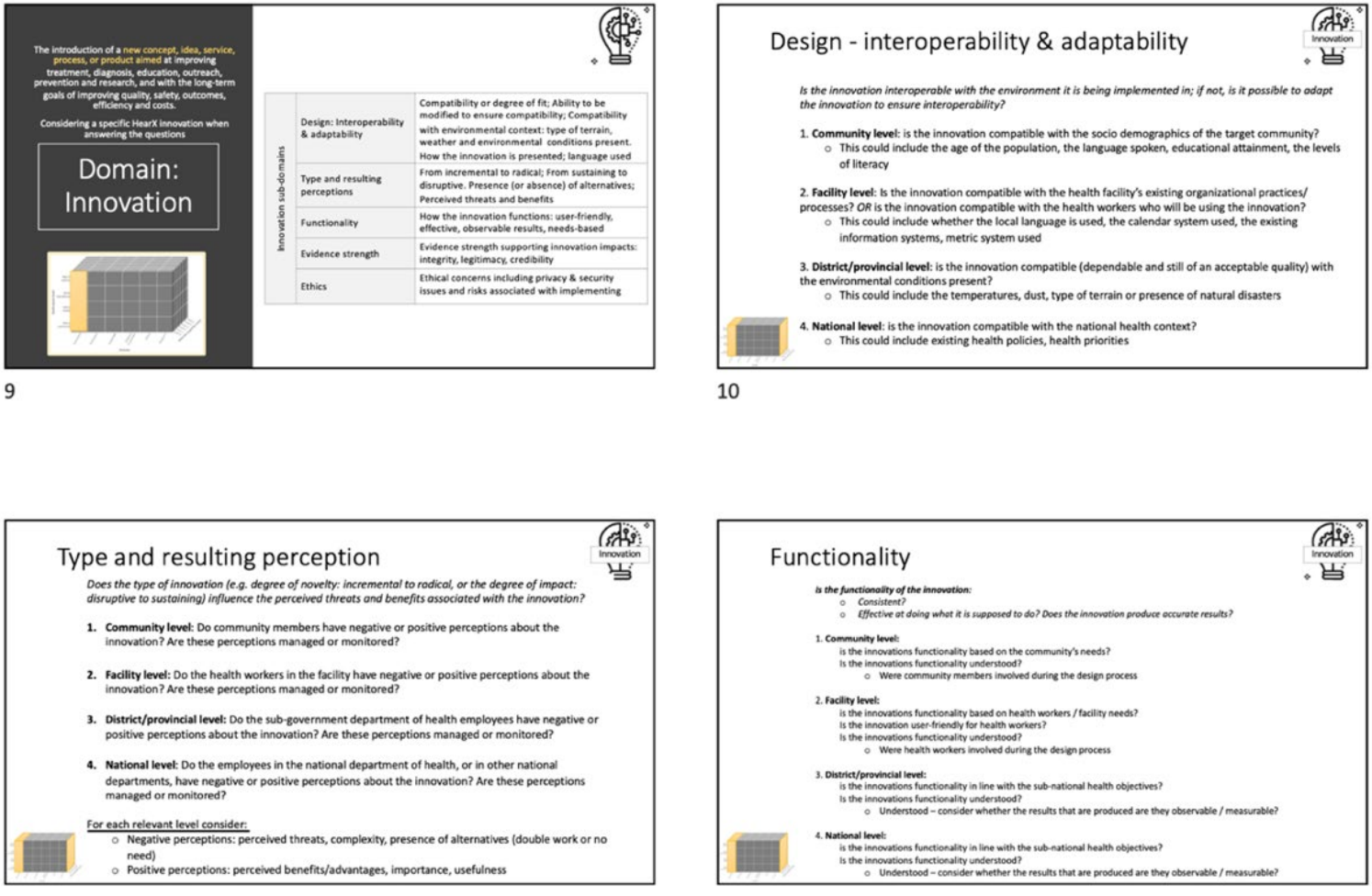
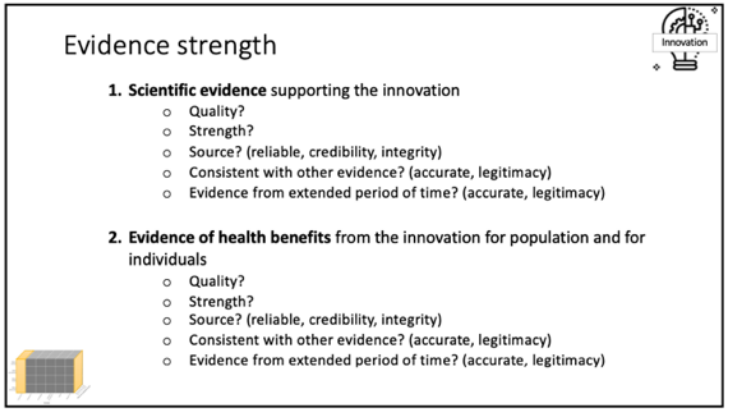


Figure J-1: Verification case study presentation



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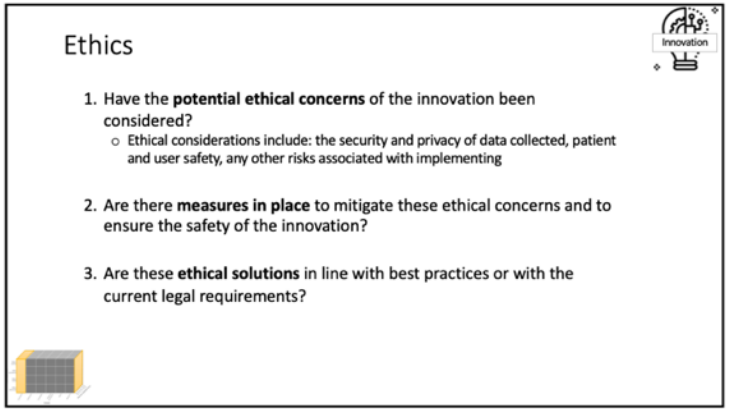

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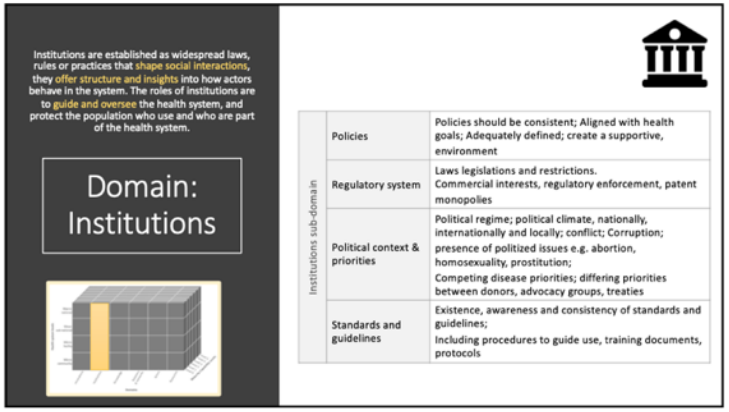

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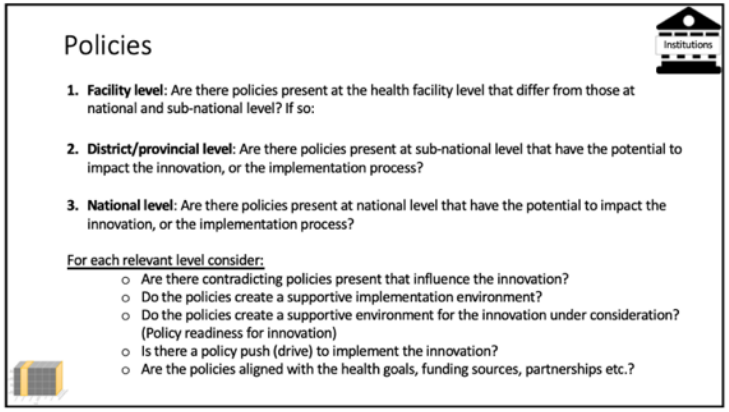

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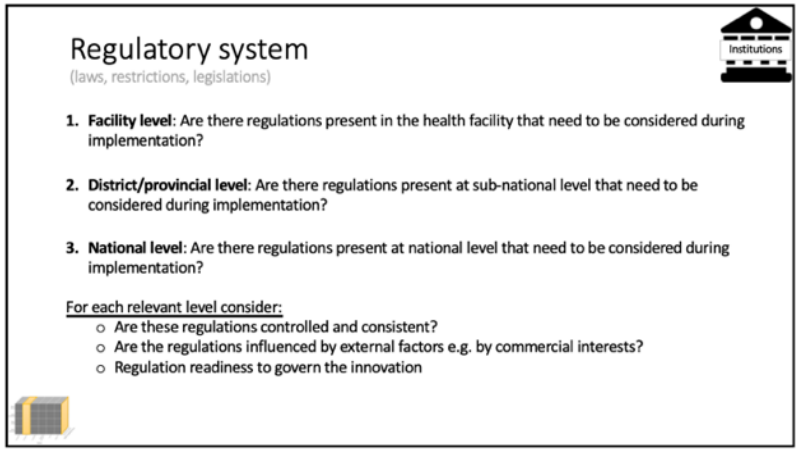

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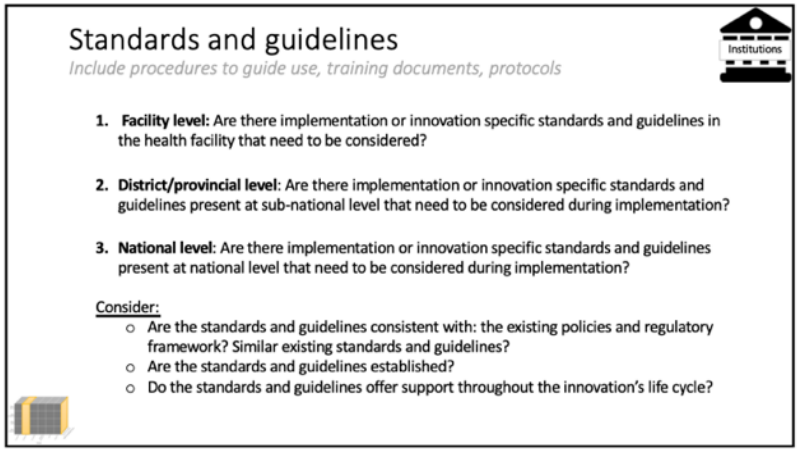

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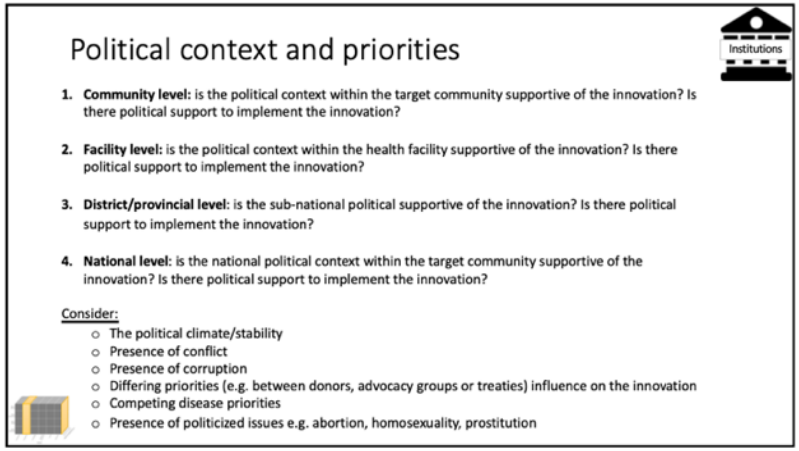

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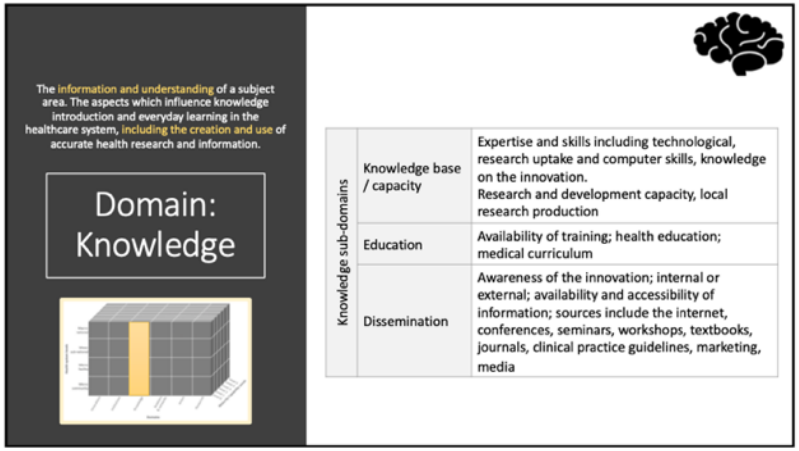

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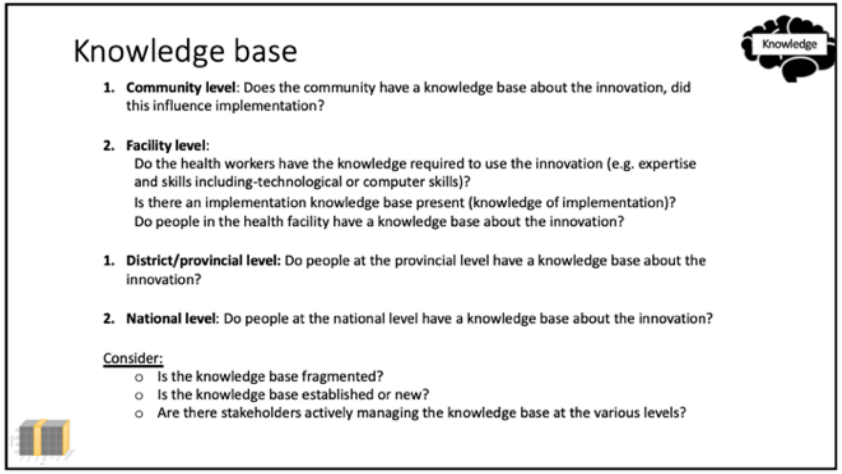

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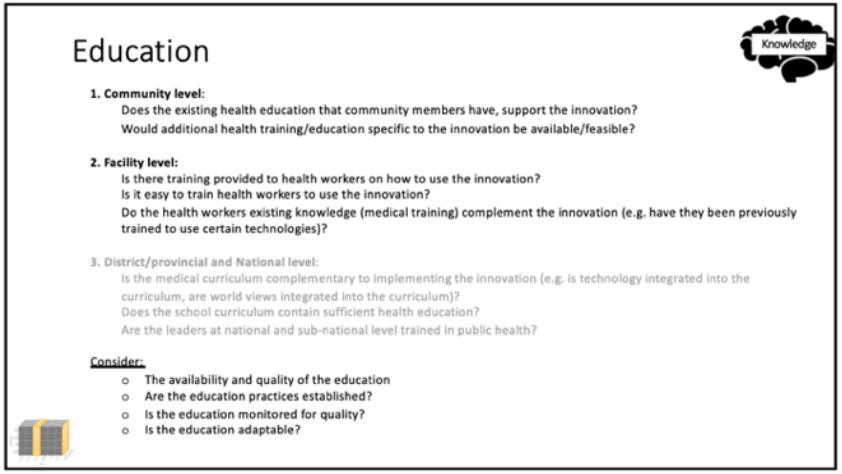

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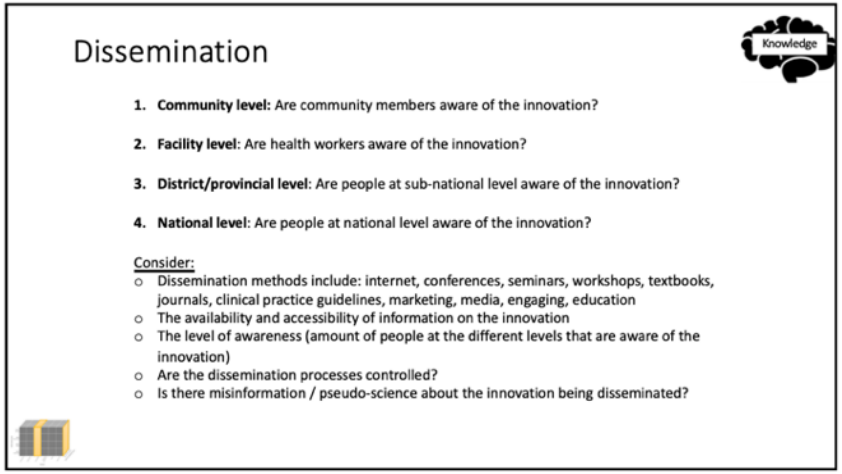

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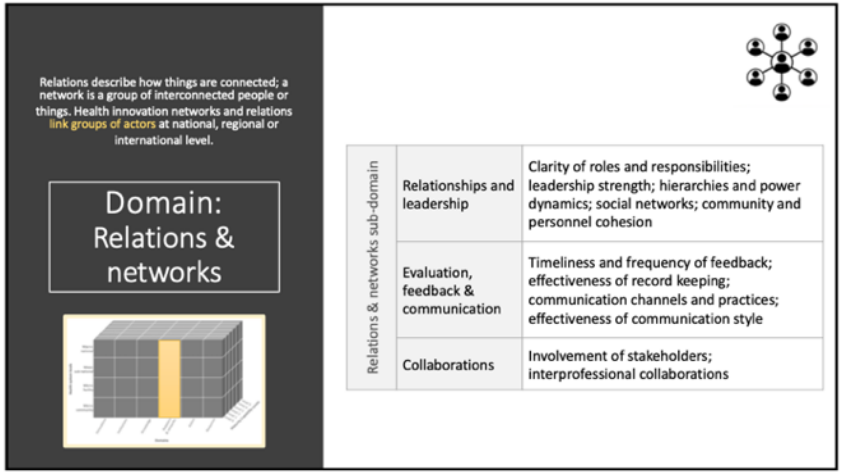

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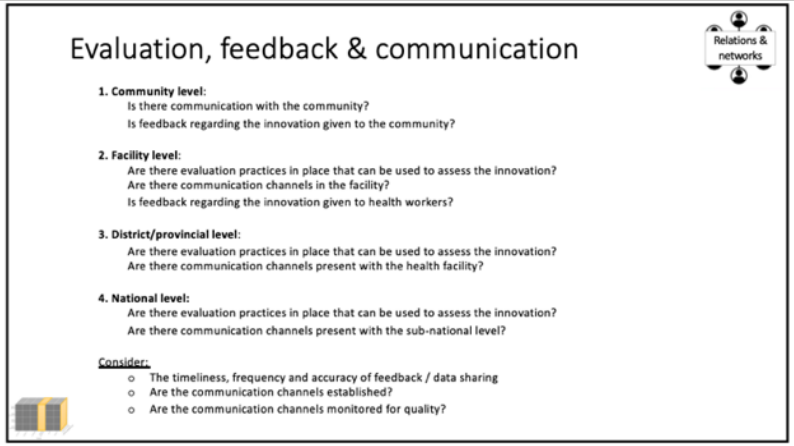

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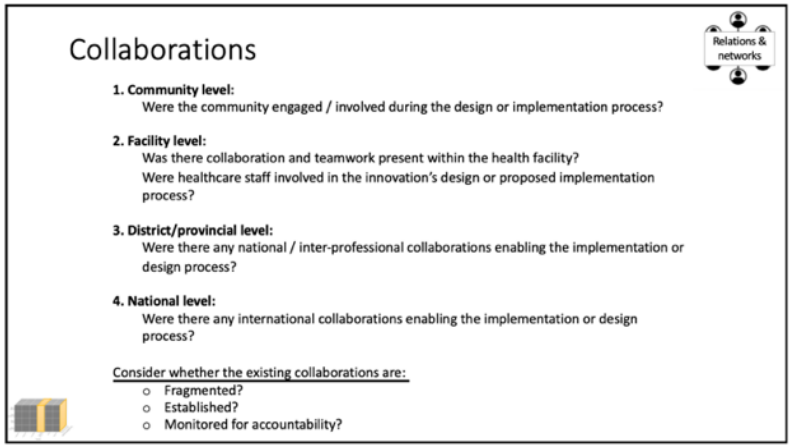

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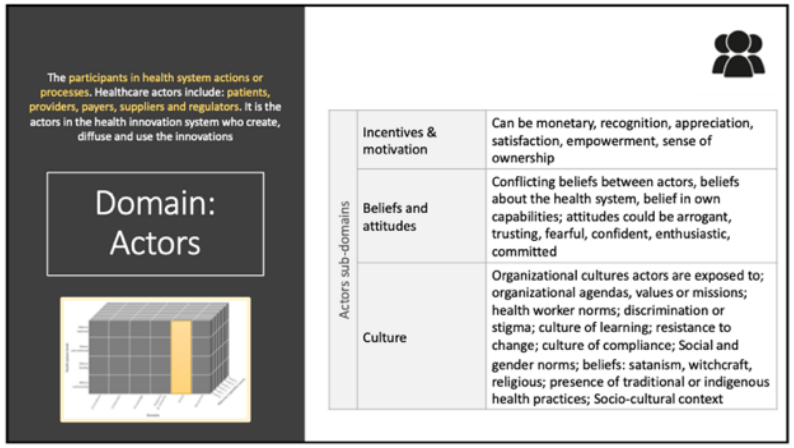

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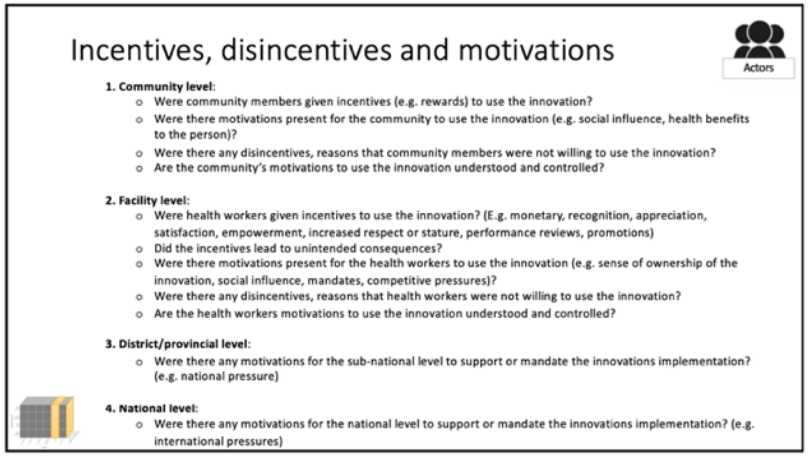

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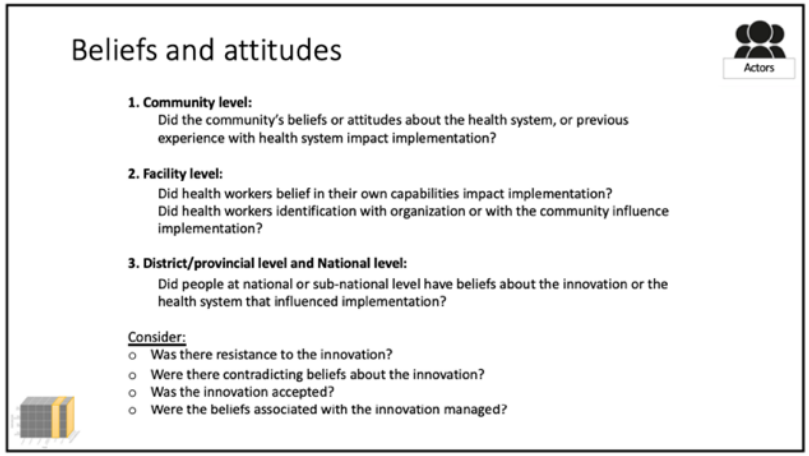

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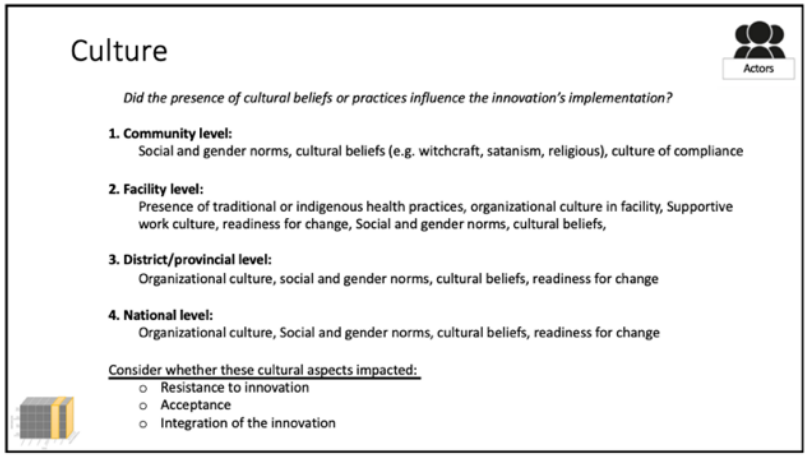

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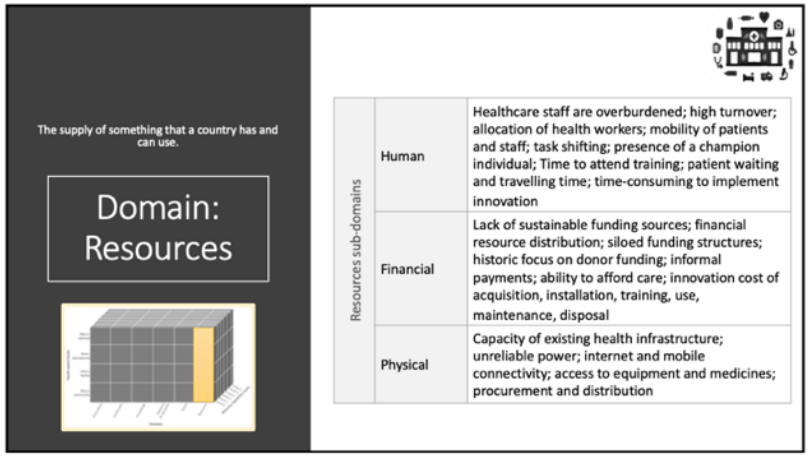

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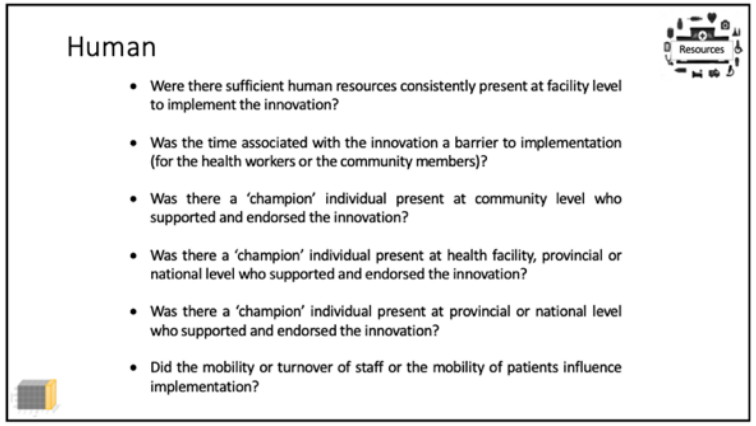

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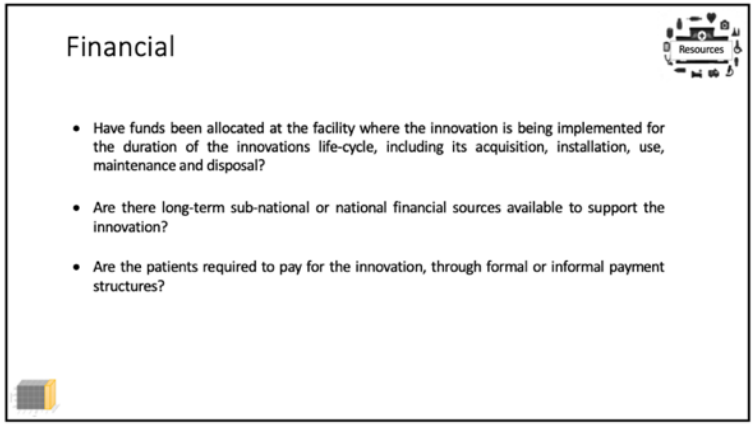

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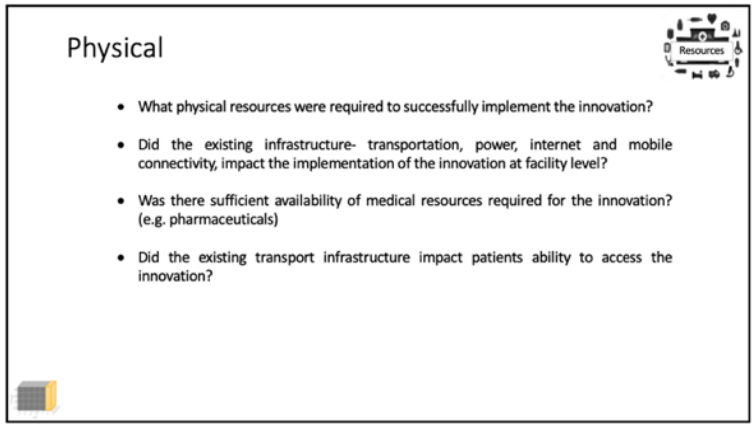

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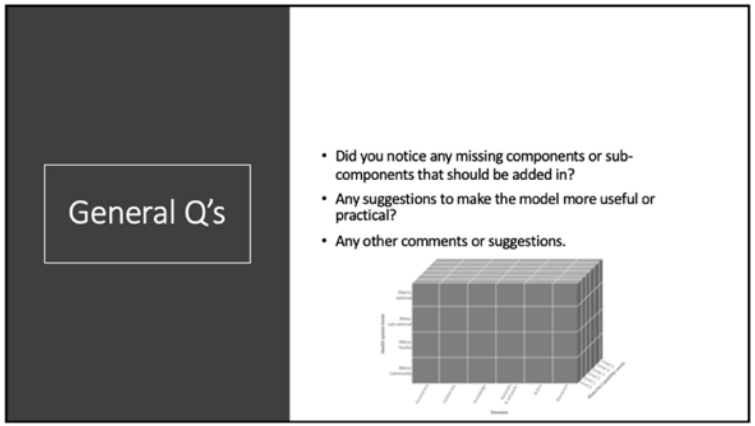

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J.2 Verification Case Study Results: Implementation of a mHealth Audiology Device in Tembisa, South Africa

The verification case study was conducted on a mHealth[30] company's device implemented in a Tembisa in South Africa; the case study was conducted to determine whether the developed maturity model is usable and applicable in a real-life scenario in an LMIC health system.

The selected health innovation was developed by a South African mHealth (mobile health) company specialising in audiology. The health innovation company is kept anonymous, in line with the REC ethical guidelines. The innovation being considered for this case study is a decentralised hearing and vision screening device. The screening device comprises calibrated headphones and an evidence-based mobile application loaded onto a smartphone. The innovation is an affordable and mobile alternative to traditional audiology devices. The screening is automated, allowing non-specialists to conduct the screenings.

a) Verification Case Study Health System Levels

Before beginning the data collection process, the micro-, meso- and macro- health system levels were defined. The innovation is being implemented in South Africa, an upper-middle-income country (The World Bank, 2019). The South African health system consists of three tiers; the National Department of Health, the Provincial Departments of Health and the District Health System (National Department of Health, 2017a). The South African health system is decentralised, and the District Health Systems are managed by the Provincial Departments of Health (National Department of Health, 2017a). For this case study, the District Health System will be analysed at the meso-health system level, and the Provincial and National Departments of Health will be analysed at the macro-health system level. This distinction was made because the District Health System deals with health service provision. In contrast, the Provincial and National Departments of health function to manage and provide oversight.

Over two years, the innovation was applied in Tembisa, a township in the Ekurhuleni Metropolitan Municipality in the Gauteng province. Thus, the specific meso-health system level is the Ekurhuleni District Health System. The micro-health facility level comprised CHWs trained to perform the screening services. The community beneficiaries of the innovation were children aged four to seven at primary schools and early childhood development centres in Tembisa; the community level extends to include the children's parents and teachers.

b) Verification Case Study Results: Innovation Domain

The sub-domains of the innovation domain that were assessed in the verification case study are design, type & resulting threats & benefits, functionality, evidence strength and ethics. The data relevant to each sub-domain were analysed to determine their maturity levels. The average maturity level for the innovation domain was identified as 3,95.

[30] Abbreviation of mobile health. mHealth, a sub-section of eHealth, is the term used to describe mobile technologies that are used in support of healthcare services (World Health Organization, 2011).

(i) Design

For the design sub-domain, all the health system levels are identified at maturity level 4 because while the innovation is fully interoperable with the health system, there is no continuous assessment to ensure optimal interoperability. Thus, the average maturity level for the design sub-domain is 4.

The innovation's compatibility with the community's socio-demographics was considered at the micro-community level. The predominant languages spoken in Tembisa are Sepedi (33,1%), isiZulu (21,7%) and Xitsonga (13,3%) (Statistics South Africa, 2011). The innovation is interoperable with the community – the innovation's interfaces are simple; for the hearing screening, the child has to raise their hand when they hear the beeping tone, and the CHW performs a practical demonstration before beginning the screening. The screenings are fast, taking on average less than a minute to administer; thus, they do not take much time out of the school day. The instructions given to the children during the screening are verbal, with some images. The mobile application is in English, but the CHW gave the children the instructions in their home language.

For the micro-facility level, the compatibility of the innovation with the CHW was considered. The innovation's design is interoperable with the CHW. The screening is automated, allowing non-specialists to conduct the screenings, and minimal training is required to operate the innovation. The CHWs were hired and trained to administer screenings for children in schools and early childhood development centres. While the mobile application is in English, the screeners received training before beginning the screenings, and thus any misunderstandings were dealt with before the screening started.

For the meso-level, the compatibility of the innovation with the local environment was considered. The main concern at the meso-level was the ambient noise levels that could influence the screening results. To address this, the innovation continuously measures the ambient noise to ensure it is below the maximum permissible limit. Thus, the innovation is interoperable with the meso-level.

For the macro-level, the compatibility of the innovation with the national health context was considered. South Africa has a 2015-2019 mHealth strategy with the mission to "*apply mHealth as an integral part of delivery of health care services in order to meet information communication, health education and data management needs of the health system in South Africa*" (Department of Health, 2015a, p.9). The macro-health system level is thus compatible with the mHealth innovation.

(ii) Type & Resulting Threats & Benefits

The average maturity level for the type & resulting threats & benefits domain was identified as 2,5. Once the innovation and its benefits had been explained to the teachers and parents, there were no threats surrounding it. However, some parents still did not give their child permission to be screened without providing a reason. At the micro-facility level, there were no threats surrounding the innovation. The innovation has low complexity, and its importance was made clear to the CHW during their training. The CHW perceptions were monitored during retraining sessions to ensure the benefits of the innovation were retained. At the meso-level, the district health facilities involved in the project had positive perceptions of the innovation due to having prior knowledge and understanding of its benefits. The macro-level maturity level is at *level 0* because the NDOH was unaware of the innovation.

(iii) Functionality

The average maturity level for the functionality sub-domain was identified as 4,25. The innovation's functionality has been clinically validated. The functionality of the innovation at the micro-community level is at level 5. The innovation is needs-based, consistent, and efficient. Most paediatric hearing loss is preventable; however, globally nearly 34 million children have mild to severe hearing loss, and a disproportionate number of these children live in LMIC (Yancey *et al.*, 2019). It is estimated that 60% of hearing loss in children is preventable (World Health Organization, 2019a); the innovation is needs-based. The innovation's functionality is continuously being improved and added to by the innovation company.

The proposed maturity level at the micro-facility level is level 5. The innovation is based on the CHW's need for an efficient, understandable, user-friendly, and predictable screening method. The results of the testing are instantaneously observable to the CHW, who are then able to decide whether rescreening is necessary.

The proposed maturity level at the meso-level is level 5. Early identification and interventions can reduce the costs associated with treating hearing loss in children (Yancey *et al.*, 2019). Therefore, having a cost and time-effective method of screening hearing could decrease the burden on the under-resourced and over-utilised district health systems. The observable screening results can easily be summarised and shared with the stakeholders at the sub-national level.

The proposed maturity level at the macro-level is level 2. The innovation is in line with the national health objectives, specifically the goal of the 2012 Integrated School Health Policy, to "*contribute to the improvement of the general health of school-going children as well as the environmental conditions in schools and address health barriers to learning in order to improve education outcomes of access to school, retention within school and achievement at school*." (Departments of Health and Basic Education, 2012, p.10). However, the assessment level cannot be above level 2 because stakeholders at the national level are not aware of the institution; therefore, it is not possible to know whether they would understand the innovation.

(iv) Evidence Strength

All the maturity levels are proposed to be at level 5. Thus, the average maturity level for the evidence strength sub-domain is 5. There is robust and quality evidence supporting the innovation. The innovation and its use in practice have been published in academic peer-reviewed journals. Substantial evidence supports the population health benefits associated with using the innovation. Early detection and interventions in children with hearing impairment can improve outcomes, particularly in terms of language (Verhaert *et al.*, 2008; Ching *et al.*, 2013).

(v) Ethics

All the maturity levels are proposed to be at level 4. Thus, the average maturity level for the ethics sub-domain is 4. Prior to any child being screened, a signed consent form had to be received from their parents; the micro-community ethical considerations were managed. No safety risks were associated with operating or using the innovation; the headphones were sterilised at regular intervals to ensure infection control. When considering the ethical concerns at the meso- and macro-levels, the security of the data collected is considered. The data is encrypted using the Advanced Encryption Standard 256-bit encryption and secured using token-based authentication to ensure the privacy of the data collected during the screening process.

c) *Verification Case Study Results: Institutions Domain*

The sub-domains of the institutions domain in the refined preliminary maturity model are policies, regulatory system, standards & guidelines and political context & priorities. The data relevant to each sub-domain were analysed to determine their maturity levels. The average maturity level for the institutions domain was identified as 2,73.

(i) Policies

The average maturity level for the policies sub-domain is 1,33. No policies were found for the micro-facility and meso-sub-national levels; thus, the maturity levels for these health system levels were identified as level 0. The South African national policies relevant to the innovation include:

i. The 2015-2019 mHealth strategy: the mission of the policy is to "*apply mHealth as an integral part of delivery of health care services*" (Department of Health, 2015a, p.9).
ii. The 2012 integrated school health policy: the goal of the policy is to "*contribute to the improvement of the general health of school-going children*"; the policy states that all foundational phase children are required to have health screenings which include hearing screening (Departments of Health and Basic Education, 2012, p.10).
iii. The National Health Promotion Policy and Strategy: this policy is based on numerous existing regional and international health declarations that South Africa is part of. The strategy's vision is to provide "*a long and healthy life for all South Africans through the promotion of healthy lifestyle practices and wellness*" (Department of Health, 2015b, p.9).
iv. The Health Promoting Schools Program: this program was developed to "*provide common ground for alliance between government departments (particularly health and education)*" (WHO Regional Office for Africa, 2013, p.2).
v. The 2005-2010 National integrated plan for early childhood development in South Africa: the plan aims to provide "*an integrated approach for converging basic services for improved childcare, early stimulation and learning, health and nutrition, water and sanitation*" (UNICEF and South African Government, 2005, p.11).
vi. The 2017 national adolescent and youth health policy: the vision is to ensure "*a long and healthy life for all South African adolescents and youth*" (Department of Health, 2017, p.1).

The national policy environment in South Africa is considered supportive of mHealth innovations and ensuring children have access to health services, such as hearing screening. Therefore, the national health system level's maturity was identified as level 4.

(ii) Regulatory System

The average maturity level for the regulatory system sub-domain is 4. The South African regulations relevant to implementing the mHealth innovation include the following:

i. Electronic Communications Act 36 of 2005;
ii. Independent Communications Authority of South Africa Act 3 of 2006;
iii. The Protection of Personal Information Act 4 of 2013;
iv. The National Health Act 61 of 2003;
v. The Constitution of South Africa Act 108 of 1996;
vi. The Children's Act 38 of 2005; and

vii. The Medicines and Related Substances Amendment Act 14 of 2015.

These acts cover the data the innovation collects, the regulations surrounding medical devices and the right to healthcare services. Within each act, various regulations need to be adhered to. The regulations are established and understood, and commercial interests do not influence them; therefore, the maturity level proposed is level 4.

(iii) Standards & Guidelines

The average maturity level for the standards & guidelines sub-domain is 3,33. The micro- and meso-levels were identified as maturity level 3. The innovation company developed documents to guide CHWs' use and documents mapping out the referral pathway for the district health system. At the meso-level, there are existing international and national standards. The International Organization for Standardization (ISO) has a health informatics technical committee (ISO/TC 215) that develops standards for health information and communications technology (International Organization for Standardization, 1998). ISO guidelines are internationally recognised and established, ensuring consistency internationally; therefore, the macro-maturity level is at level 4. The innovation is calibrated according to international and national standards; the headphones are calibrated according to ISO 389-1.

(iv) Political Context & Priorities

The average maturity level for the political context & priorities sub-domain is 2,23. At the micro-community level, there was so-called political support from the majority of schools; the school's endorsement of the innovation meant that parents had greater trust in the innovation. Hence the micro-community level was identified as level 3. At the micro-facility level, among the CHW, there was accountability and so-called political support from the CHW leader. There was some conflict between the CHW, but this was resolved amicably. Therefore, the micro-facility level was identified as level 4. At the meso-level, in the district health system, there was political support for the two years that the project was carried out (temporary support). Thus, the maturity level was identified as level 2. There was no political support from the national level; therefore, the maturity level was identified as level 0.

d) Verification Case Study Results: Knowledge

The sub-domains of the knowledge domain in the refined preliminary maturity model are knowledge base & capacity, education and dissemination. The data relevant to each sub-domain were analysed to determine their maturity levels. The average maturity level for the knowledge domain was identified as 2,42.

(i) Knowledge Base & Capacity

The average maturity level for the knowledge base & capacity sub-domain is 2,25. The maturity level at the micro-community level was identified as level 2. At the micro-community level, the knowledge base surrounding the innovation and hearing screening is new, with only a proportion of the population having the appropriate knowledge base. The community's knowledge base is mostly a result of the information provided on the parent consent forms and teachers' discussions with CHW. At the micro-facility level, the maturity was identified as level 4. All CHWs have the knowledge base needed to use the innovation (ability to work with digital technologies, communication skills,

administrative and reporting skills, and ability to work with children). The CHW knowledge base was managed using repeat training sessions and feedback sessions. Level 3 was chosen for the meso-level. At the meso-level, most district health providers had the appropriate knowledge of the innovation. At the national level, there was no awareness of the innovation; hence the maturity level was identified as level 0.

(ii) Education

The average maturity level for the education sub-domain is 3,25. The highest education levels obtained in Tembisa according to the 2011 census are (Statistics South Africa, 2011): (i) 3,7% of the population have no schooling; (ii) 7,2% of the population completed some primary education; (iii) 3,4% completed primary; (iv) 38,3% completed some secondary; (v) 39,9% achieved matric; and (vi) 7,5% completed higher education.

At the micro-community level, there was information provided to the parents through the informed consent documents. As part of the project, there were also two community awareness events, to educate community members on the effects of and how to identify hearing and vision impairments in children. Therefore, level 2 was chosen for the micro-community level. At the micro-facility level, the CHW received three-hour training sessions on how to use the innovation. Retraining sessions were provided where necessary. The training sessions also provided the CHW with information on the importance of screening to ensure accurate information was provided at the schools. Hence, level 3 was chosen for the micro-facility level.

Level 4 was chosen for both the meso- and macro-levels. At the meso-level, there was an established education base as most actors had medical training; no additional training was required for the meso-level actors. At the macro-level, the presence of public health education for national leaders in South Africa was considered. Public health provides leaders with the ability to optimise and manage the health system (IJsselmuiden *et al.*, 2007). In the AfriHealth[31] project, advanced public health education was mapped throughout Africa; at the time of the project, South Africa had more than four public health schools (IJsselmuiden *et al.*, 2007).

(iii) Dissemination

The average maturity level for the dissemination sub-domain is 1,75. Level 2 was chosen for both micro-community and micro-facility levels. At the micro-community level, dissemination of the innovation was controlled, and community members were made aware of the innovation through consent forms and community awareness events. At the micro-facility level, the CHWs were made aware of the innovation when they were approached to be part of the project. Level 3 was chosen for the meso-level. At the meso-level, some of the district health system actors were aware of the innovation, having become aware of it from journal and from news articles. Level 0 was chosen for the macro-level; at the macro-level, there was poor awareness, and thus dissemination, of the innovation.

[31] http://www.cohred.org/cohred-archive/african-schools-of-public-health-afrihealth/

e) *Verification Case Study Results: Relations & Networks*

The sub-domains of the relations & networks domain in the refined preliminary maturity model are relations & leadership, collaborations, and evaluation, feedback & communication. The data relevant to each sub-domain were analysed to determine their maturity levels. The average maturity level for the relations & networks domain was identified as 2,92.

(i) Relationships & Leadership

The average maturity level for the relationships & leadership sub-domain is 3. Level 4 was chosen for both the micro-community and micro-provider levels. At the micro-community level, the positive relationships between the school and parents' facilitated the parents buy-in of the innovation. At the micro-facility level, a natural hierarchy among the CHW occurred, with one CHW taking a leadership role. There was also a project manager who oversaw the CHW. Level 3 was chosen for the meso-level. At the meso-level there is formalised leadership within the district health system. There were no formalised relationships between the CHW and the meso-level. At the macro-level, level 1 was chosen; any relationships at the macro-level associated with the innovation were fragmented or did not exist.

(ii) Evaluation, Feedback & Communication

The average maturity level for the evaluation, feedback & communication sub-domain is 2,75. Level 5 was chosen for the micro-community level. At the micro-community level, accurate and timely feedback was provided to the school principal once the screenings had been completed. Once a child had been screened, an SMS was sent to their parents with the results. If a child had to be referred for treatment, a letter was sent home with them emphasising the importance of going for the referral. Level 3 was chosen for the micro-facility level. There were miscommunications between the CHW and school staff, and some did not understand the purpose of the screening. At the micro-facility level, the CHW had established and understood communication channels. Level 3 was chosen for the meso-level. At the meso-level, the communication practices were established and understood. At the macro-level, no communication channels existed; hence maturity level 0 was chosen.

(iii) Collaborations

The average maturity level for the collaborations sub-domain is 3. Level 4 was chosen for the micro-community, micro-facility, and meso-levels. At the micro-community level, there was a collaboration with a Tembisa-based company that assisted with implementation. At the micro-facility level, there were collaborations between the CHWs. The CHW themselves were from the Tembisa community, further strengthening the community collaborations. At the meso-level, there were inter-professional collaborations between schools and district health facilities. There were no macro-level collaborations; hence maturity level 0 was chosen.

f) *Verification Case Study Results: Actors*

The sub-domains of the actor's domain in the refined preliminary maturity model are culture, beliefs & attitudes, and motivation. The data relevant to each sub-domain were analysed to determine their maturity levels. The average maturity level for the actors domain was identified as 2,83.

(i) Motivations

The average maturity level for the motivations sub-domain is 3,5. Level 4 was chosen for both the micro-community and micro-facility levels. At the micro-community level, the motivation to participate in the screenings was a result of the potential health benefits for the children. At the micro-facility level, the CHWs were incentivised to participate in the project by receiving a monthly salary for the project's duration. Level 3 was chosen for both the meso- and macro-level. The meso-level incentives to participate in the project were the reduced burden on the district health systems. Participating in the project gave the district health facilities the innovation to use. The macro-level incentives include achieving the South African national health objectives.

(ii) Beliefs & Attitudes

The average maturity level for the beliefs & attitudes sub-domain is 2. Level 1 was chosen for the micro-community level; at the micro-community level, the community beliefs about the health system resulted in a poor follow-up rate by the parents at the district health facilities. Level 3 was chosen for the micro-facility level. The innovation was accepted at micro-community level by the majority of parents and teachers and at the micro-facility level by all of the CHW. Level 4 was chosen for the meso-level; at the meso-level, there was some uncertainty about the accuracy of the innovation. However, this was managed by performing a demonstration of the innovation. The macro-level stakeholders were unaware of the innovation; hence maturity level 4 was chosen.

(iii) Culture

The average maturity level for the culture subdomain is 3. Level 2 was chosen for the micro-community level. One school was who were initially resistant to allowing the program into their school because the CHW screening team consisted of isiZulu and Setswana speakers, and the school was a Tshivenda school. Level 3 was chosen for the micro-facility level; the CHW supported and accepted the innovation. Level 4 was chosen for the meso-level; the district health facilities had a receptive culture and accepted the innovation. Level 3 was chosen for macro-level; the macro-level was unaware of the innovation. However, there are no foreseen cultural barriers at the national level that would prevent the innovation's implementation; considering the existing national policies, the innovation is in line with the national culture.

g) Verification Case Study Results: Resources

The sub-domains of the resource's domain in the refined preliminary maturity model are human, financial and physical. The data relevant to each sub-domain were analysed to determine their maturity levels. The average maturity level for the resources domain was identified as 2,75.

(i) Human

The average maturity level for the human resources sub-domain is 1,75. Level 2 was chosen for the micro-community level. At the micro-community level, the patient waiting time was minimal because of the short time required to complete the screening. There was some community mobility; during the follow-up period, some children who needed referrals had moved and could not be located. The

schools acted as the innovation champions[32], encouraging parents to allow their children to be screened. The Tembisa-based implementation partner acted as the anthropologist[33] and networker[34] at the community level.

Level 2 was chosen for the micro-facility level. At the micro-facility level, there were sufficient human resources available. However, the CHWs were only hired for the duration of the project. At the project's beginning some CHWs who left, so new CHWs had to be hired and trained. A coordinator[35] and networker were present who managed the project and the CHW. The CHW acted as the anthropologists and innovation champions; the CHW were from Tembisa and understood the culture there. Level 3 was chosen for the meso-level; the presence of human resources in the district system able to assist with the project, is consistent and long-term. At the macro-level, no human resources participated in or championed the project; hence maturity level 0 was chosen.

(ii) Financial

The average maturity level for the financial resources sub-domain is 1,25. Level 1 was chosen for the micro-community level. At the micro-community level, even though the initial screenings were free and conducted at the schools, some of the children who had to attend referral appointments were unable to because of financial constraints. Parents could not take time off work or afford the transportation costs to take their children to appointments. Level 2 was chosen for both micro-facility and meso-level. At the micro-facility and meso-levels, the funding supporting the project was temporary. The grant received funded the project for two years. No macro-level funds were made available; hence level 0 was chosen.

(iii) Physical

The average maturity level for the physical resources sub-domain is 2,75. Level 2 was chosen for the micro-community level. At the micro-community level, sufficient physical resources were in place to ensure the children could access the innovation. However, these resources were only available for the duration of the project. Level 3 was chosen for the micro-facility level. At the micro-facility level, physical resources (including mobile connectivity and power supply) were sufficient to allow the innovation to function effectively. Even if these resources were not available, the innovation would still be able to function by saving the data offline to upload when there was connectivity and by ensuring the smartphone's battery was fully charged. Level 3 was chosen for both the meso- and macro-levels. The procurement of and distribution of auditory devices was sufficient to ensure the referred children had access to the auditory treatments.

h) Verification Case Study: Discussion

The design & functionality of the innovation is well suited to a resource-constrained setting. The innovation addresses the need in LMIC for an evidence-based, affordable, easily understandable and accessible hearing screening. One suggestion for the innovation's design is to include an option

[32] The "champion" is the actor(s) who is committed to and promotes the innovation (Essmann and Du Preez, 2009);
[33] The "anthropologist" is the actor(s) who understands the people interacting with the innovation, their culture and behaviour (Essmann and Du Preez, 2009);
[34] The "networker" is the actor(s) who creates connections with individuals and organisations (Essmann and Du Preez, 2009);
[35] The "coordinator" is the actor(s) who manages the implementation process (i.e. a project manager) (Essmann and Du Preez, 2009);

to change the application's language to the local language, allowing for even greater interoperability with CHW. When considering the institutions domain, it is clear that South Africa has a supportive regulatory and policy environment. However, there was no political support for the innovation, which influenced the project's longevity. It is recommended that protocols or policies are established at the facility level to facilitate CHW communication, feedback channels and conflict management.

The importance of understanding the cultural context and managing the actor's beliefs was emphasised in the actor's domain. In the resource's domain, partnering with national actors is recommended to ensure a more sustainable funding source. In the human resources domain, the mobility of patients should be considered.

When considering the knowledge and the relations & networks domains it is recommended that the national health department establish a dissemination channel to encourage health innovation companies to collaborate with the department of health. By encouraging national collaborations and support, the sustainability of evidence-based health innovations could increase, which increase the percentage of the population who could benefit from the innovation. Another recommendation is to improve the community's knowledge base on health; this could be achieved by improving health education in primary schools or considering alternative health dissemination paths. In Tembisa 94,1% of households had a cell phone, 71,2% of households had a television and 60,2% had a radio (Statistics South Africa, 2011); these existing dissemination channels could be used to broadcast information on the importance of hearing and vision screening. During their education, teachers should be taught to identify signs that indicate hearing or sight problems in children.

J.3 Validation Case Study: COVID Alert

This section presents the content supporting the COVID Alert case study (see Chapter 9, Section 9.3.3) is presented. First, the survey, sent to participants, is presented; thereafter, the survey results.

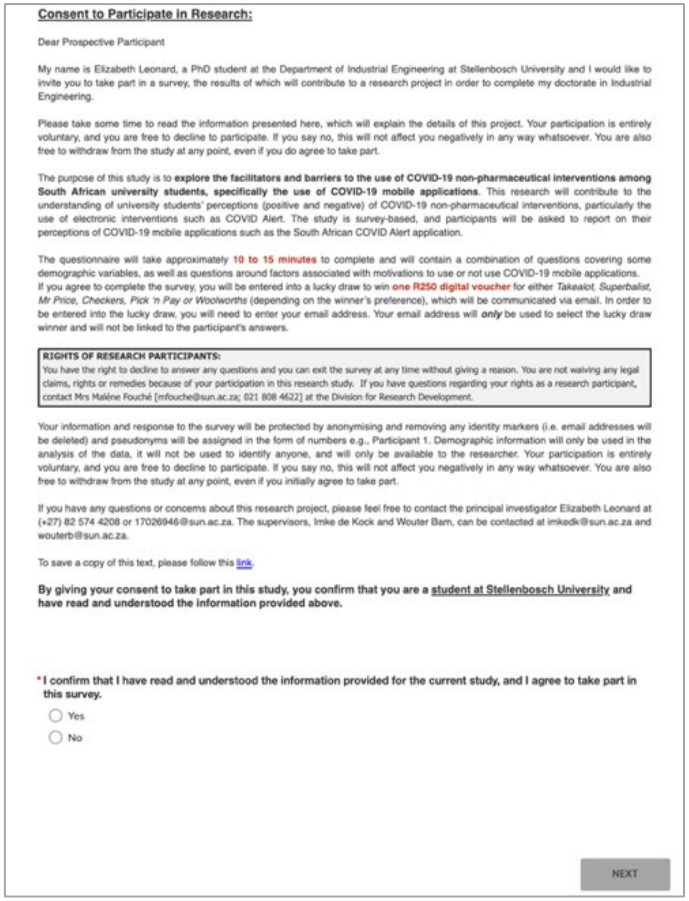
a) COVID Alert Survey Methodology

The advantages of using surveys as a data collection tool include their (i) ability to collect information from a large number of people efficiently, (ii) using minimal resources, as well as (iii) their ability to provide insights into a population group, which may not have been realised from observation alone (Glasow, 2005). Disadvantages of surveys include the possibility of biases due to poor response rates or inaccurate responses being given (Glasow, 2005). The following steps describe the process followed when conducting the COVID Alert survey. These are a combination of the steps proposed by Groves *et al.* (2009) and Glasow (2005):

i. Define the objectives of the survey;
ii. Develop a sampling strategy:
    (a) Identify the target population being investigated; and
    (b) Determine the sample size;
iii. Design and construct the survey instrument;
iv. Execute the survey; and
v. Code, edit, analyse and present the data.

b) COVID Alert Survey Questions

Figure J-2 shows the survey completed by participants who partook in the COVID Alert case study.



Consent to Participate in Research:

Dear Prospective Participant

My name is Elizabeth Leonard, a PhD student at the Department of Industrial Engineering at Stellenbosch University and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my doctorate in Industrial Engineering.

Please take some time to read the information presented here, which will explain the details of this project. Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

The purpose of this study is to **explore the facilitators and barriers to the use of COVID-19 non-pharmaceutical interventions among South African university students, specifically the use of COVID-19 mobile applications**. This research will contribute to the understanding of university students' perceptions (positive and negative) of COVID-19 non-pharmaceutical interventions, particularly the use of electronic interventions such as COVID Alert. The study is survey-based, and participants will be asked to report on their perceptions of COVID-19 mobile applications such as the South African COVID Alert application.

The questionnaire will take approximately **10 to 15 minutes** to complete and will contain a combination of questions covering some demographic variables, as well as questions around factors associated with motivations to use or not use COVID-19 mobile applications.
If you agree to complete the survey, you will be entered into a lucky draw to win **one R250 digital voucher** for either *Takealot, Superbalist, Mr Price, Checkers, Pick 'n Pay or Woolworths* (depending on the winner's preference), which will be communicated via email. In order to be entered into the lucky draw, you will need to enter your email address. Your email address will ***only*** be used to select the lucky draw winner and will not be linked to the participant's answers.

RIGHTS OF RESEARCH PARTICIPANTS:
You have the right to decline to answer any questions and you can exit the survey at any time without giving a reason. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact Mrs Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Your information and response to the survey will be protected by anonymising and removing any identity markers (i.e. email addresses will be deleted) and pseudonyms will be assigned in the form of numbers e.g., Participant 1. Demographic information will only be used in the analysis of the data, it will not be used to identify anyone, and will only be available to the researcher. Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you initially agree to take part.

If you have any questions or concerns about this research project, please feel free to contact the principal investigator Elizabeth Leonard at (+27) 82 574 4208 or 17026946@sun.ac.za. The supervisors, Imke de Kock and Wouter Bam, can be contacted at imkedk@sun.ac.za and wouterb@sun.ac.za.

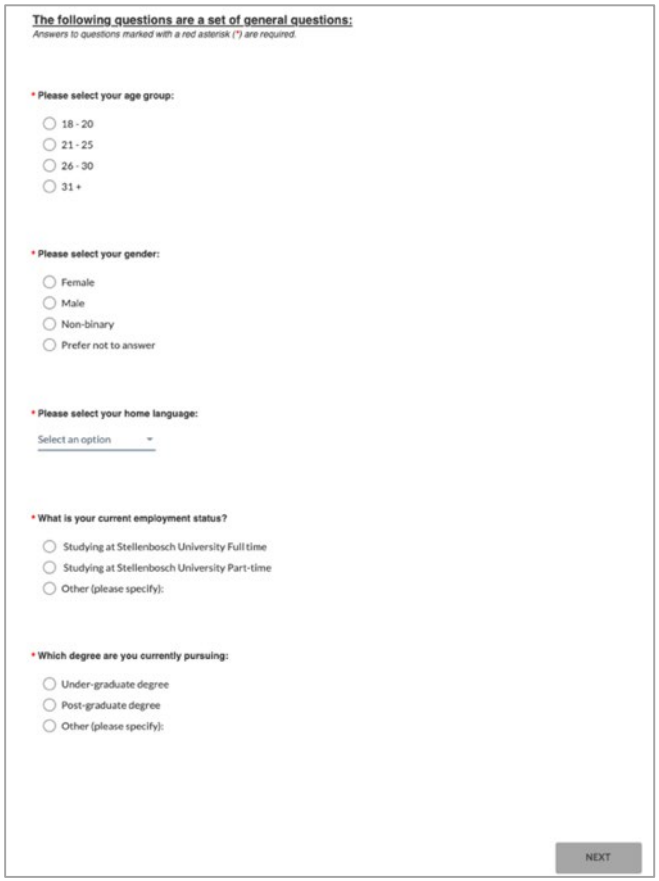
To save a copy of this text, please follow this link.

By giving your consent to take part in this study, you confirm that you are a student at Stellenbosch University and have read and understood the information provided above.

*** I confirm that I have read and understood the information provided for the current study, and I agree to take part in this survey.**

- Yes
- No

NEXT



The following questions are a set of general questions:
Answers to questions marked with a red asterisk (*) are required.

*** Please select your age group:**

- 18 - 20
- 21 - 25
- 26 - 30
- 31 +

*** Please select your gender:**

- Female
- Male
- Non-binary
- Prefer not to answer

*** Please select your home language:**

Select an option

*** What is your current employment status?**

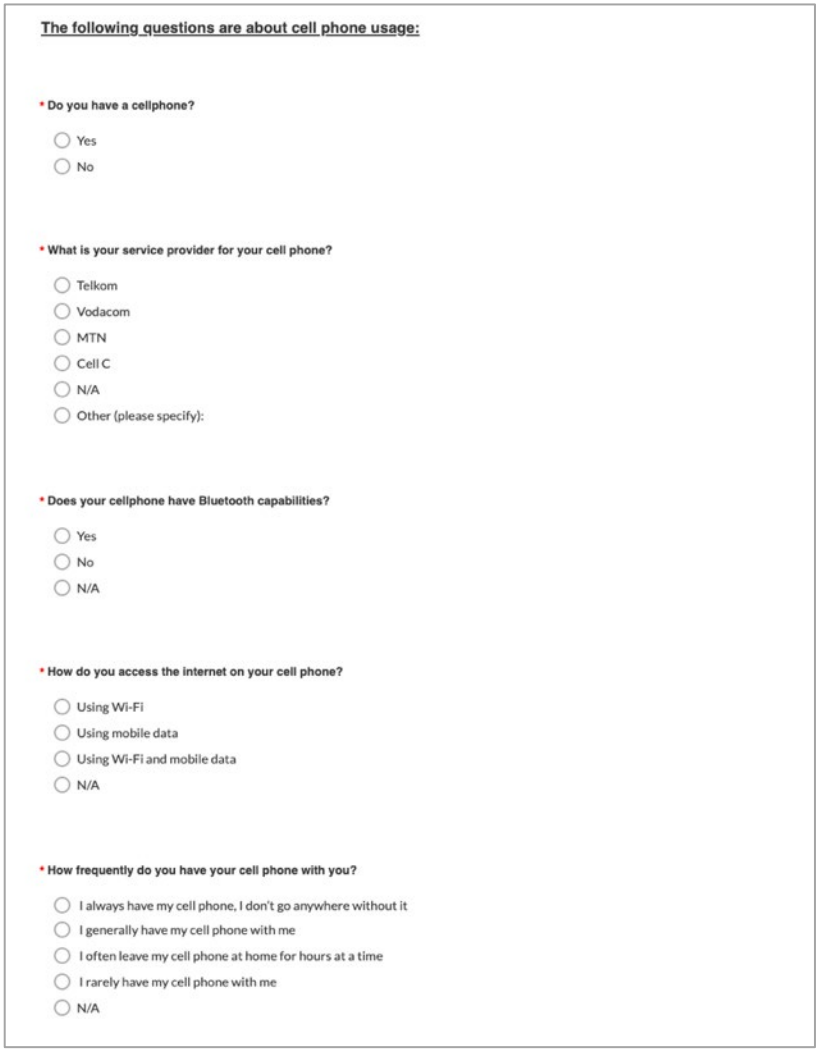
- Studying at Stellenbosch University Full time
- Studying at Stellenbosch University Part-time
- Other (please specify):

*** Which degree are you currently pursuing:**

- Under-graduate degree
- Post-graduate degree
- Other (please specify):

NEXT

Figure J-2: COVID Alert survey



The following questions are about cell phone usage:

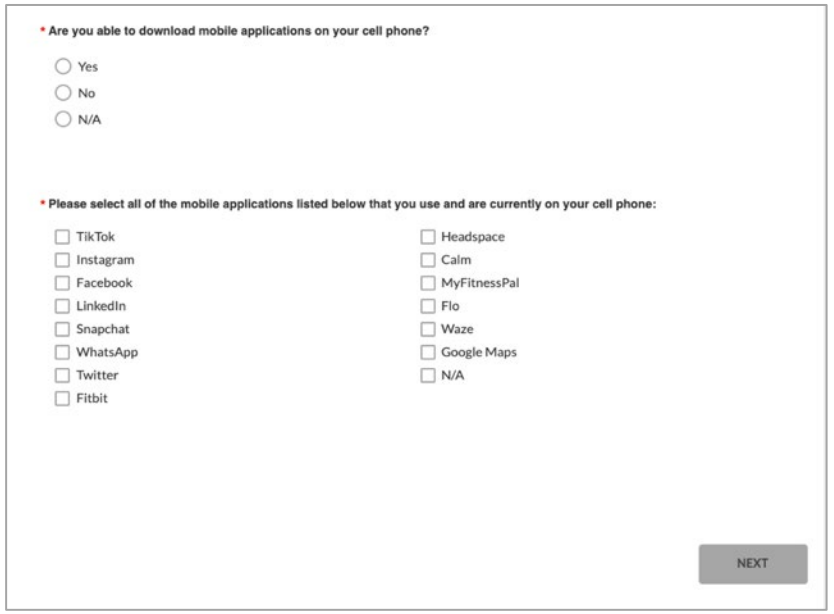
* Do you have a cellphone?
- Yes
- No

* What is your service provider for your cell phone?
- Telkom
- Vodacom
- MTN
- Cell C
- N/A
- Other (please specify):

* Does your cellphone have Bluetooth capabilities?
- Yes
- No
- N/A

* How do you access the internet on your cell phone?
- Using Wi-Fi
- Using mobile data
- Using Wi-Fi and mobile data
- N/A

* How frequently do you have your cell phone with you?
- I always have my cell phone, I don't go anywhere without it
- I generally have my cell phone with me
- I often leave my cell phone at home for hours at a time
- I rarely have my cell phone with me
- N/A

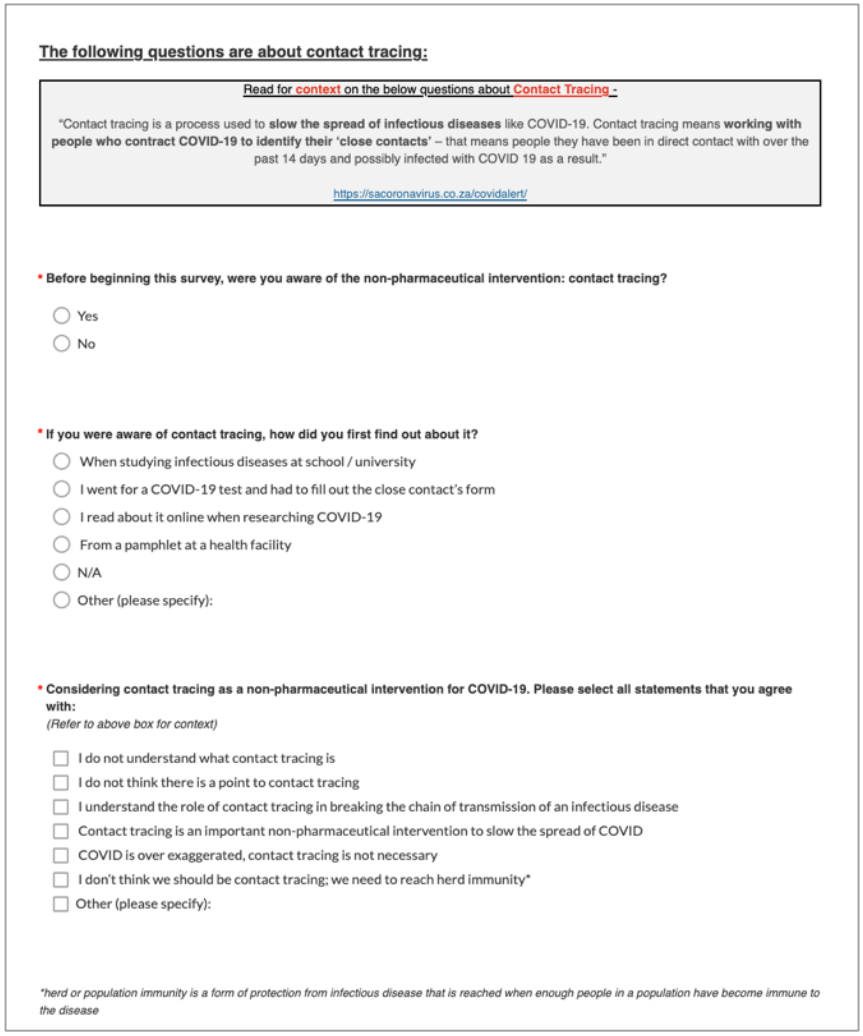


* Are you able to download mobile applications on your cell phone?
- Yes
- No
- N/A

* Please select all of the mobile applications listed below that you use and are currently on your cell phone:
- TikTok
- Instagram
- Facebook
- LinkedIn
- Snapchat
- WhatsApp
- Twitter
- Fitbit
- Headspace
- Calm
- MyFitnessPal
- Flo
- Waze
- Google Maps
- N/A

NEXT

Figure J-2 (cont.): COVID Alert survey



The following questions are about contact tracing:

Read for context on the below questions about Contact Tracing -

"Contact tracing is a process used to **slow the spread of infectious diseases** like COVID-19. Contact tracing means **working with people who contract COVID-19 to identify their 'close contacts'** – that means people they have been in direct contact with over the past 14 days and possibly infected with COVID 19 as a result."

https://sacoronavirus.co.za/covidalert/

* **Before beginning this survey, were you aware of the non-pharmaceutical intervention: contact tracing?**

- ○ Yes
- ○ No

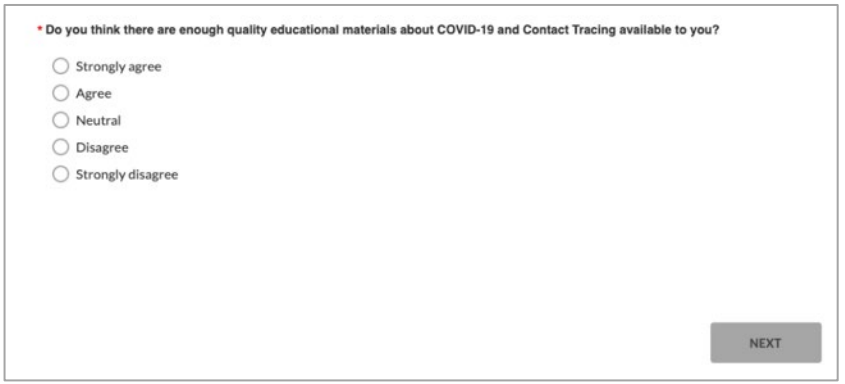
* **If you were aware of contact tracing, how did you first find out about it?**

- ○ When studying infectious diseases at school / university
- ○ I went for a COVID-19 test and had to fill out the close contact's form
- ○ I read about it online when researching COVID-19
- ○ From a pamphlet at a health facility
- ○ N/A
- ○ Other (please specify):

* **Considering contact tracing as a non-pharmaceutical intervention for COVID-19. Please select all statements that you agree with:**
(Refer to above box for context)

- ☐ I do not understand what contact tracing is
- ☐ I do not think there is a point to contact tracing
- ☐ I understand the role of contact tracing in breaking the chain of transmission of an infectious disease
- ☐ Contact tracing is an important non-pharmaceutical intervention to slow the spread of COVID
- ☐ COVID is over exaggerated, contact tracing is not necessary
- ☐ I don't think we should be contact tracing; we need to reach herd immunity*
- ☐ Other (please specify):

*herd or population immunity is a form of protection from infectious disease that is reached when enough people in a population have become immune to the disease



* **Do you think there are enough quality educational materials about COVID-19 and Contact Tracing available to you?**

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

NEXT

Figure J-2 (cont.): COVID Alert survey

The following questions are about the mobile contact tracing application COVID Alert:

Read for context on the below questions about COVID Alert -

"COVID Alert SA is **South Africa's free exposure notification app**. It lets people know when they have been in **close contact** with someone who has **tested positive for COVID-19**. COVID Alert SA uses Bluetooth contact-tracing technology – which tracks close contact (proximity) between smartphones, and not the actual location of the smartphones. At no stage does the app reveal the users' identities. **When an app user anonymously reports to the app that they have COVID 19, the COVID Alert SA app sends notifications to those devices that were in close contact with this person's device.**"

https://sacoronavirus.co.za/covidalert/

* **Were you aware of COVID Alert before beginning this survey?**

- ○ Yes
- ○ No

* **Do you have COVID Alert downloaded onto your mobile phone?**

- ○ Yes
- ○ No

* **If you were aware of COVID Alert before beginning this survey, how did you find out about it?**

- ○ Social Media
- ○ During a presidency address
- ○ Word of mouth
- ○ From the department of health website
- ○ Radio
- ○ Television
- ○ N/A
- ○ Other (please specify):

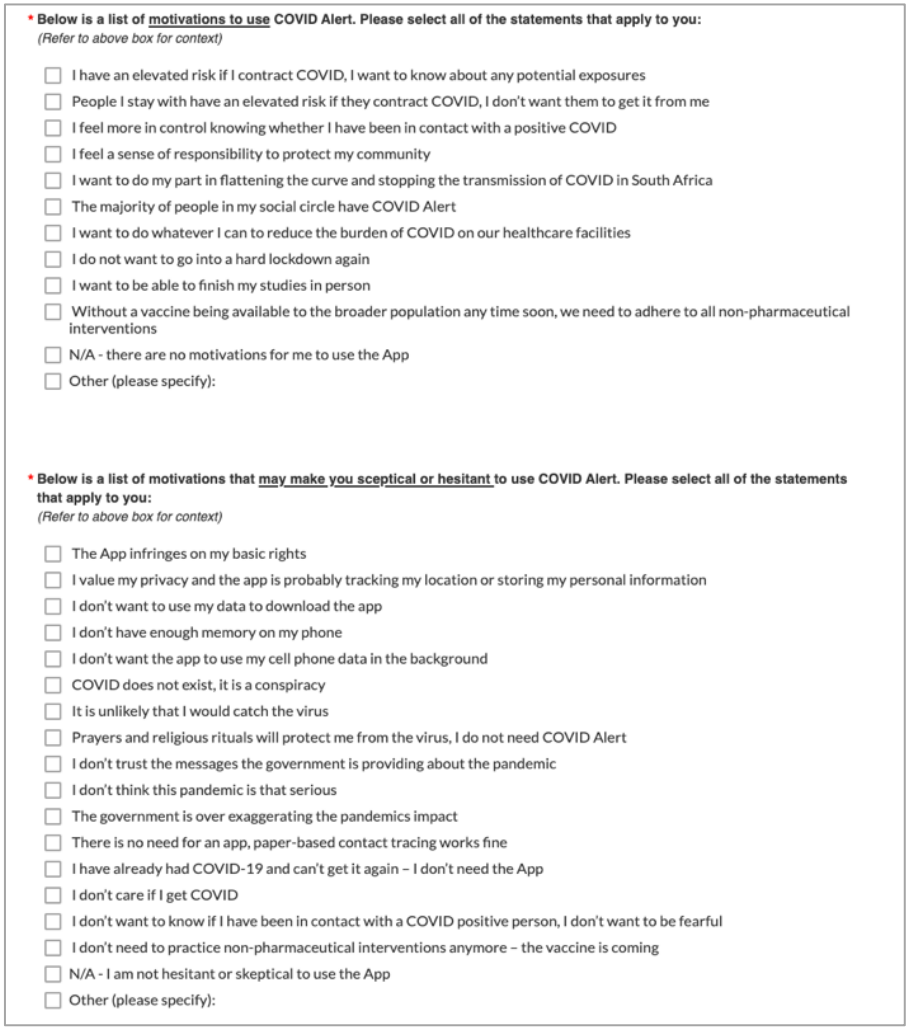
* **Please select all of the statements that you believe to be true about COVID Alert. Select all that apply:**
(Refer to above box for context)

- ☐ The government is using COVID Alert to track my movements
- ☐ My personal information is being stored on the app
- ☐ COVID Alert can only access my Bluetooth
- ☐ COVID Alert is not able to identify my location
- ☐ COVID Alert is accessing my contacts
- ☐ COVID Alert uses my location to determine whether I have been in contact with a COVID positive person
- ☐ My identity is protected on COVID Alert
- ☐ COVID Alert will notify me if I have been in close contact with someone who tested positive for COVID-19
- ☐ I can use COVID Alert to anonymously alert others if I have tested positive for COVID-19
- ☐ I have to enter my personal details if I test positive for COVID and want to alert my contacts
- ☐ My data is being collected and sold to third parties
- ☐ Other (please specify):

* **Which of the following endorsements would (or has) influence you to download COVID Alert. Select all that apply:**
(Refer to above box for context)

- ☐ World Health Organization
- ☐ President Cyril Ramaposa
- ☐ Zwelini Mkhize, the South African Minister of Health
- ☐ Blade Nzimande, the South African Minister of Higher Education, Science and Technology
- ☐ Medical professional (e.g., general practitioner)
- ☐ Campus health
- ☐ Traditional healers
- ☐ University management
- ☐ Department heads
- ☐ Western Cape premier
- ☐ Student leaders (e.g., House Committee, class representatives, SRC)
- ☐ Religious leaders
- ☐ Influencers (e.g., sport stars, social media influencers, celebrities)
- ☐ None, I would not download the app because of endorsements
- ☐ Other (please specify):

Figure J-2 (cont.): COVID Alert survey

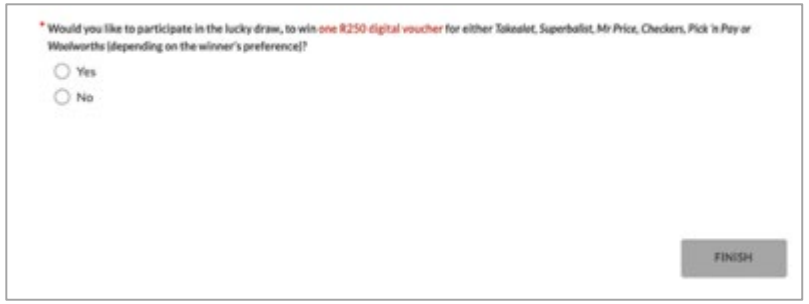


* **Below is a list of motivations to use COVID Alert. Please select all of the statements that apply to you:**
(Refer to above box for context)

- ☐ I have an elevated risk if I contract COVID, I want to know about any potential exposures
- ☐ People I stay with have an elevated risk if they contract COVID, I don't want them to get it from me
- ☐ I feel more in control knowing whether I have been in contact with a positive COVID
- ☐ I feel a sense of responsibility to protect my community
- ☐ I want to do my part in flattening the curve and stopping the transmission of COVID in South Africa
- ☐ The majority of people in my social circle have COVID Alert
- ☐ I want to do whatever I can to reduce the burden of COVID on our healthcare facilities
- ☐ I do not want to go into a hard lockdown again
- ☐ I want to be able to finish my studies in person
- ☐ Without a vaccine being available to the broader population any time soon, we need to adhere to all non-pharmaceutical interventions
- ☐ N/A - there are no motivations for me to use the App
- ☐ Other (please specify):

* **Below is a list of motivations that may make you sceptical or hesitant to use COVID Alert. Please select all of the statements that apply to you:**
(Refer to above box for context)

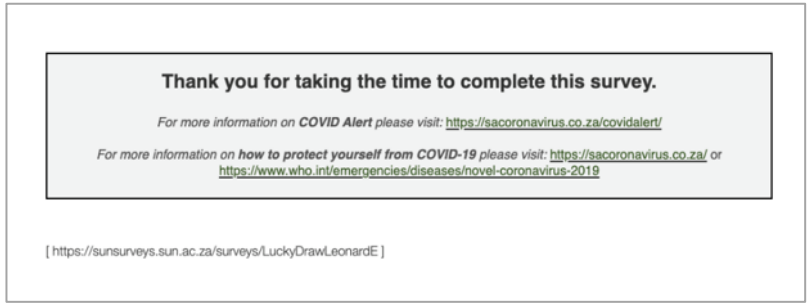
- ☐ The App infringes on my basic rights
- ☐ I value my privacy and the app is probably tracking my location or storing my personal information
- ☐ I don't want to use my data to download the app
- ☐ I don't have enough memory on my phone
- ☐ I don't want the app to use my cell phone data in the background
- ☐ COVID does not exist, it is a conspiracy
- ☐ It is unlikely that I would catch the virus
- ☐ Prayers and religious rituals will protect me from the virus, I do not need COVID Alert
- ☐ I don't trust the messages the government is providing about the pandemic
- ☐ I don't think this pandemic is that serious
- ☐ The government is over exaggerating the pandemics impact
- ☐ There is no need for an app, paper-based contact tracing works fine
- ☐ I have already had COVID-19 and can't get it again – I don't need the App
- ☐ I don't care if I get COVID
- ☐ I don't want to know if I have been in contact with a COVID positive person, I don't want to be fearful
- ☐ I don't need to practice non-pharmaceutical interventions anymore – the vaccine is coming
- ☐ N/A - I am not hesitant or skeptical to use the App
- ☐ Other (please specify):



* Would you like to participate in the lucky draw, to win one R250 digital voucher for either Takealot, Superbalist, Mr Price, Checkers, Pick 'n Pay or Woolworths (depending on the winner's preference)?

- ○ Yes
- ○ No

FINISH



Thank you for taking the time to complete this survey.

*For more information on **COVID Alert** please visit:* https://sacoronavirus.co.za/covidalert/

*For more information on **how to protect yourself from COVID-19** please visit:* https://sacoronavirus.co.za/ or https://www.who.int/emergencies/diseases/novel-coronavirus-2019

[https://sunsurveys.sun.ac.za/surveys/LuckyDrawLeonardE]

Figure J-2 (cont.): COVID Alert survey

c) COVID Alert Survey Results

This section presents the survey results supporting the COVID Alert case study. The figures presented were drawn using Checkbox®, the software used to conduct the survey. The COVID Alert case study is described in Chapter 9, Section 9.3.3.

Figure J-3 shows the age distribution of the people who participated in the survey.

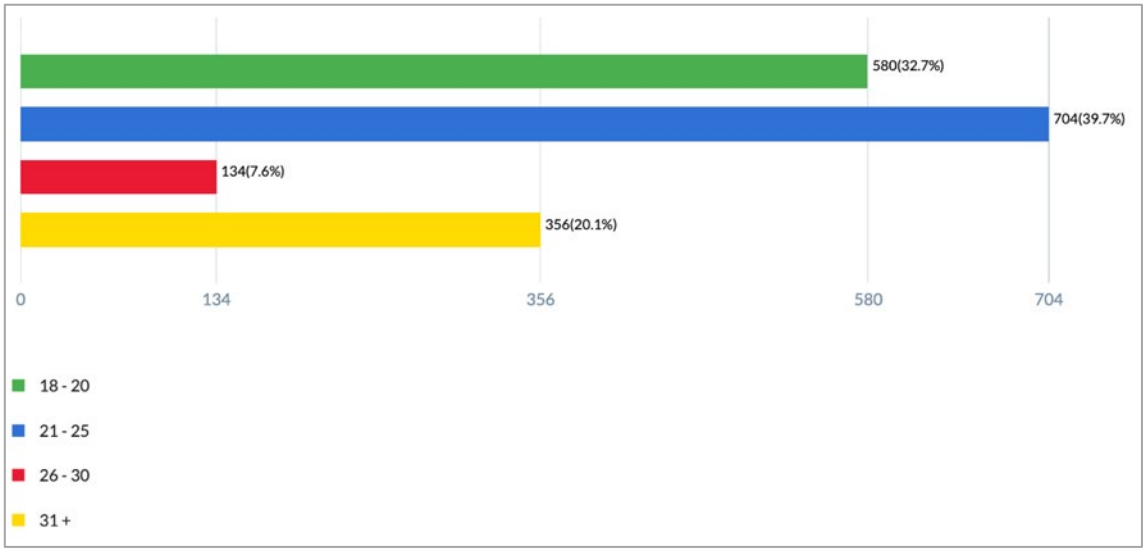


Figure J-3: COVID Alert Survey results – age group

Figure J-4 shows the gender distribution of the people who participated in the survey.

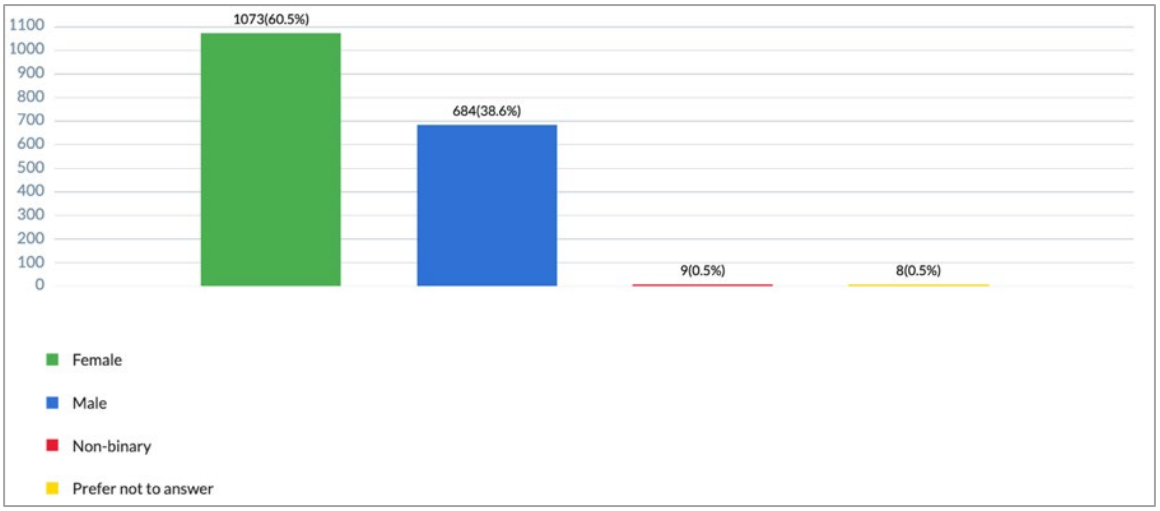


Figure J-4: COVID Alert Survey results – gender

Figure J-5 shows the survey participants' home languages.

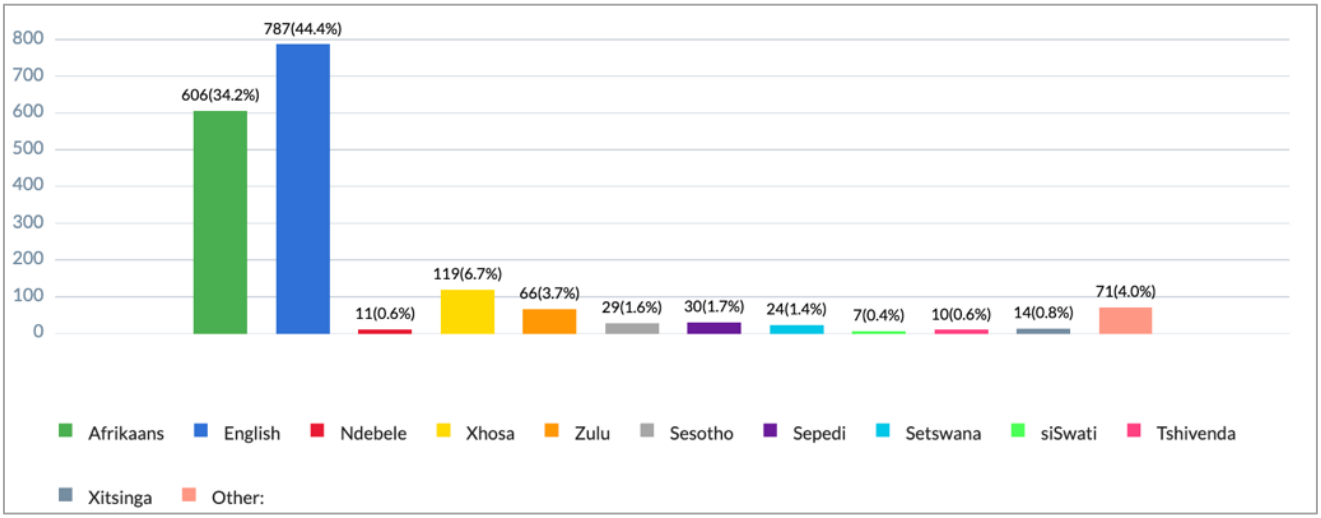


Figure J-5: COVID Alert Survey results – home language

Figure J-6 shows the distribution of the survey participants employment status.

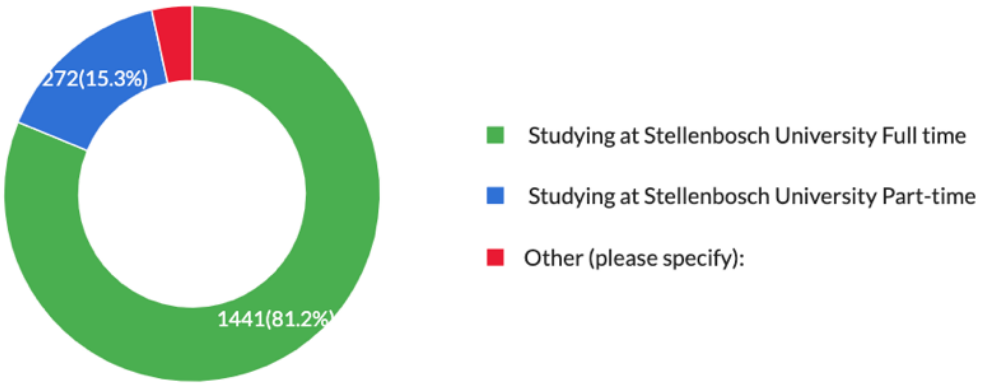


Figure J-6: COVID Alert Survey results – employment status

Figure J-7 shows the degrees that survey participants' are pursuing.

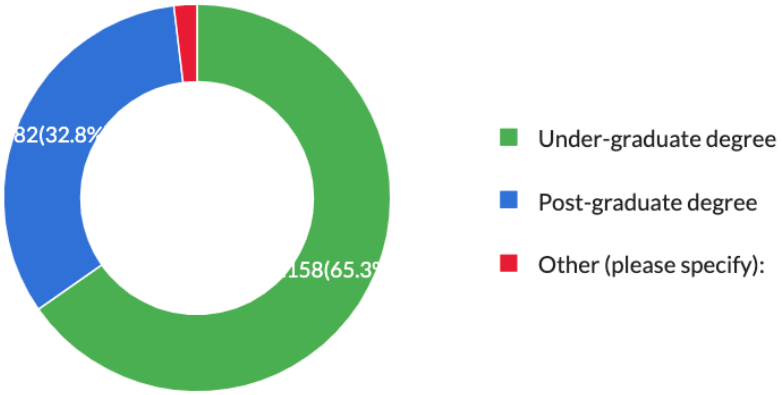


Figure J-7: COVID Alert Survey results – degree pursuing

Figure J-8 describes whether the survey participants own a cell phone.

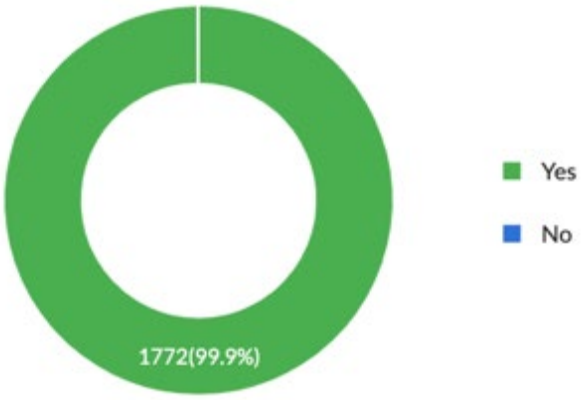


Figure J-8: COVID Alert Survey results – cell phone ownership

Figure J-9 shows the distribution of mobile network operators that survey participants use.

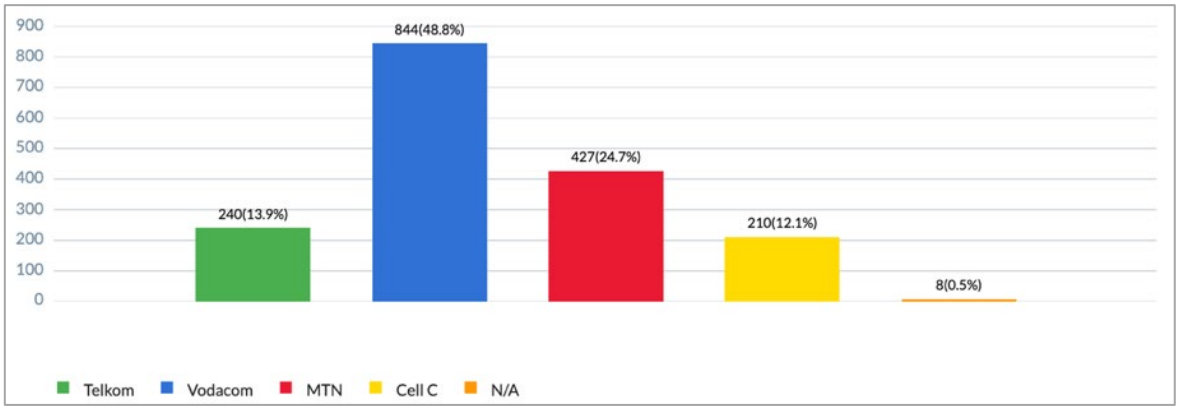


Figure J-9: COVID Alert Survey results – cell phone service provider

Figure J-10 describes whether a survey participant's mobile phone has Bluetooth capabilities.

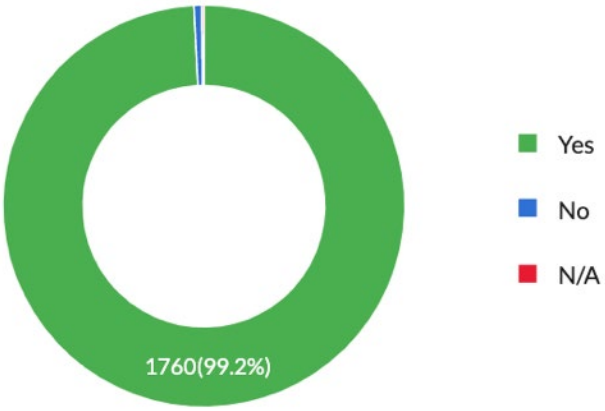


Figure J-10: COVID Alert Survey results –cell phone Bluetooth capabilities

Figure J-11 describes how survey participants access the internet on their cell phones.

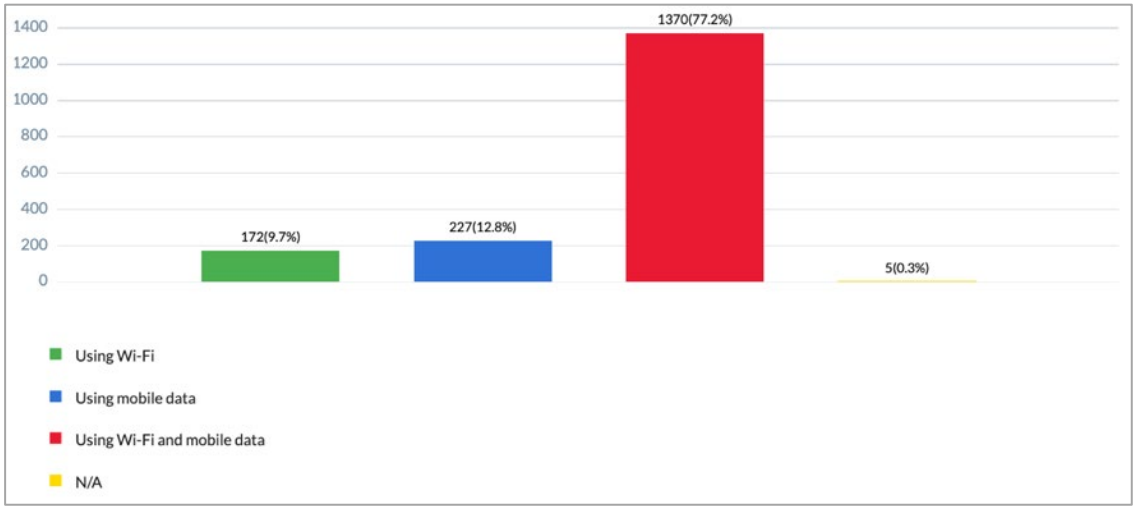


Figure J-11: COVID Alert Survey results – internet access on their cell phone

Figure J-12 shows the frequency that a person has their cell phone with them.

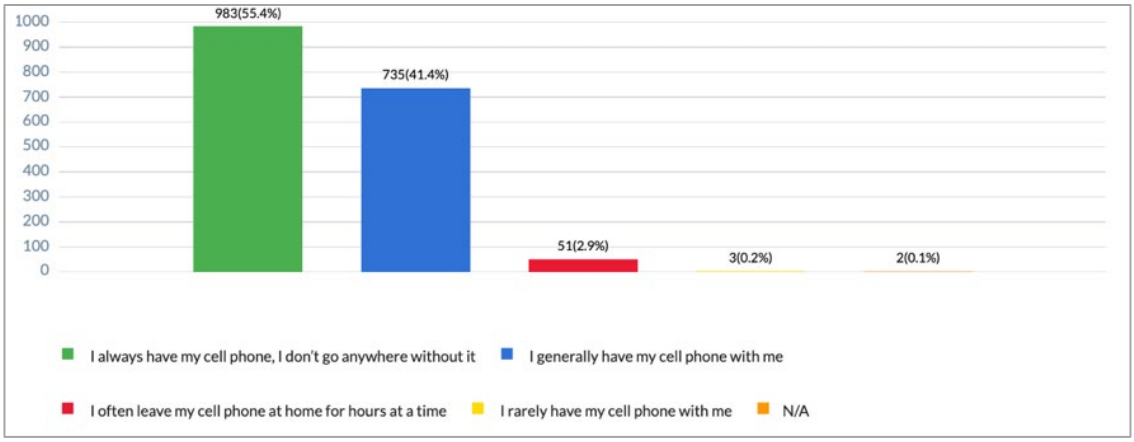


Figure J-12: COVID Alert Survey results – frequency of cell phone on your person

Figure J-13 shows the ability of survey participants to download mobile applications onto their cell phones.

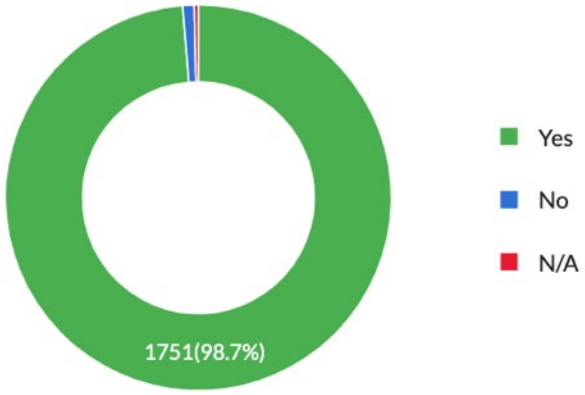


Figure J-13: COVID Alert Survey results – ability to download mobile applications

Figure J-14 shows the mobile applications that survey participants have on their cell phones.

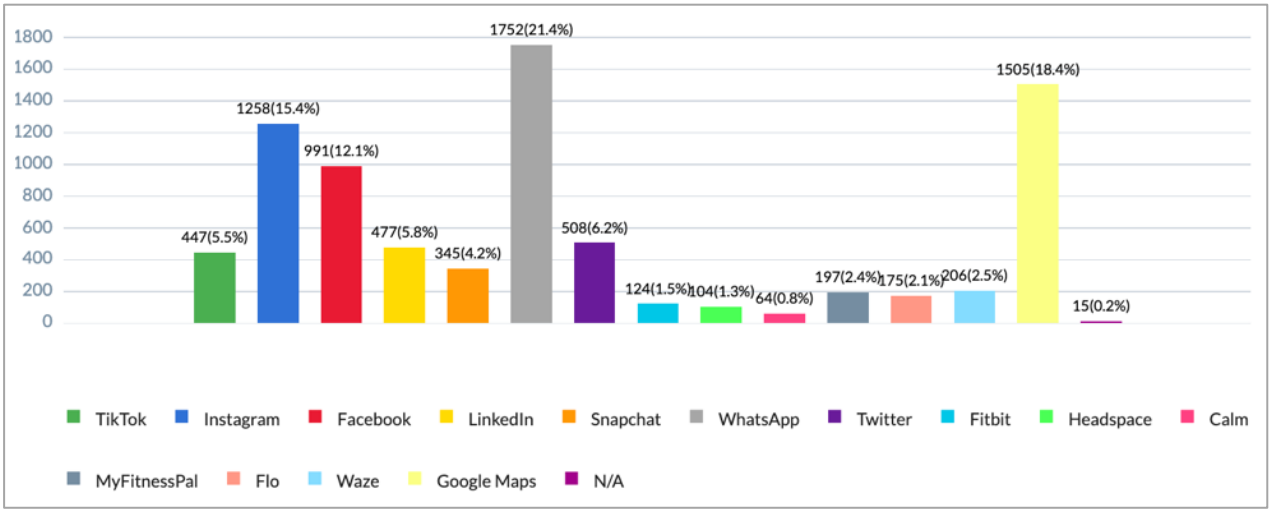


Figure J-14: COVID Alert Survey results – mobile applications currently on their cell phone

Figure J-15 shows the survey participants' awareness of the non-pharmaceutical intervention contact tracing.

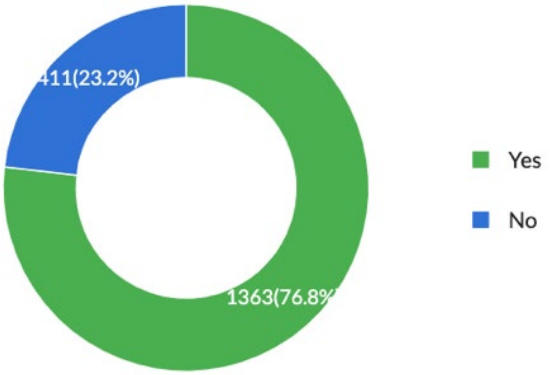


Figure J-15: COVID Alert Survey results – awareness of contact tracing

Figure J-16 shows the dissemination channels that led to people finding out about contact tracing.

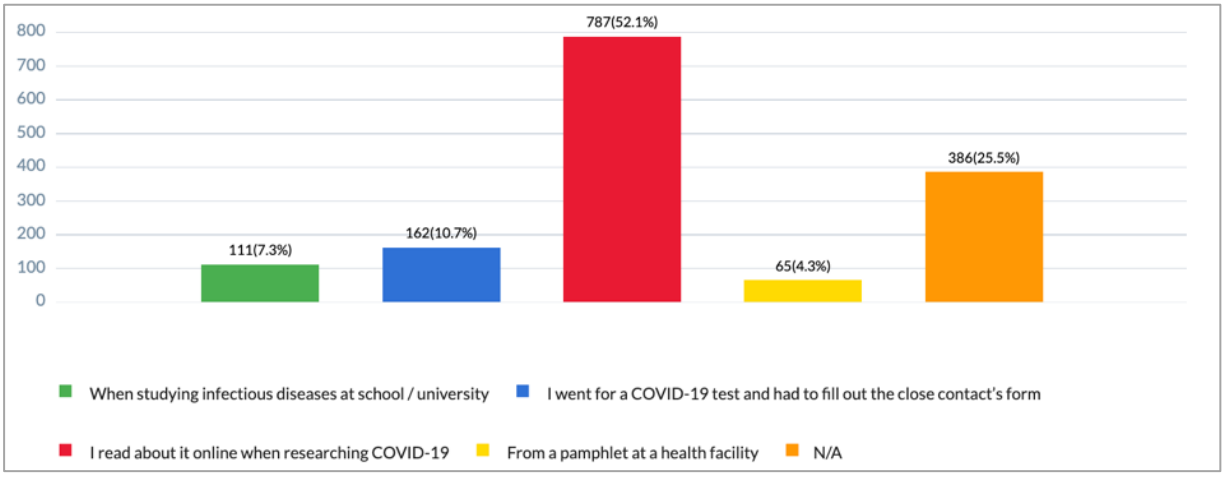


Figure J-16: COVID Alert Survey results – contact tracing dissemination channel

Figure J-17 shows survey participants' understanding surrounding contact tracing for COVID-19.

Answer	Count	Percent
I do not understand what contact tracing is	190	6.60%
I do not think there is a point to contact tracing	94	3.27%
I understand the role of contact tracing in breaking the chain of transmission of an infectious disease	1286	44.67%
Contact tracing is an important non-pharmaceutical intervention to slow the spread of COVID	1073	37.27%
COVID is over exaggerated, contact tracing is not necessary	54	1.88%
I don't think we should be contact tracing; we need to reach herd immunity*	182	6.32%

Figure J-17: COVID Alert Survey results – understanding of contact tracing for COVID-19

Figure J-18 shows whether survey participants believe there are enough quality educational materials about COVID-19 and Contact Tracing available.

Figure J-18: COVID Alert Survey results –educational materials about COVID-19 and contact tracing

Figure J-19 shows survey participants' awareness of COVID Alert before starting the survey.

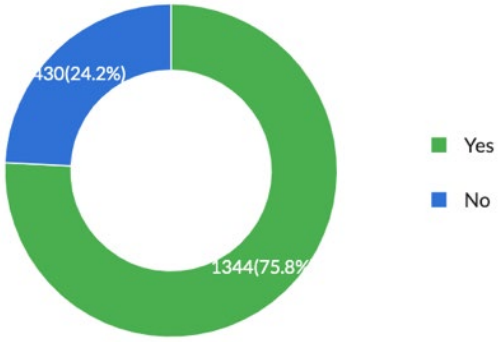


Figure J-19: COVID Alert Survey results – COVID Alert awareness

Figure J-20 shows whether survey participants had COVID Alert downloaded on their phones.

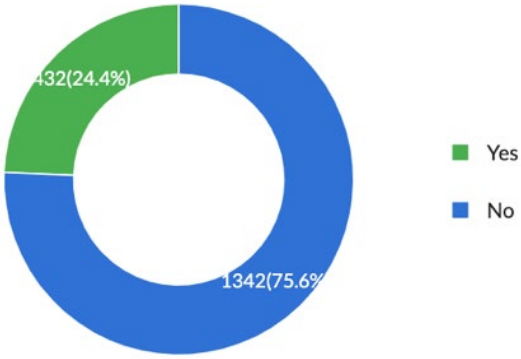


Figure J-20: COVID Alert Survey results – COVID Alert downloaded

Figure J-21 shows the dissemination channels that led to people finding out about COVID Alert.

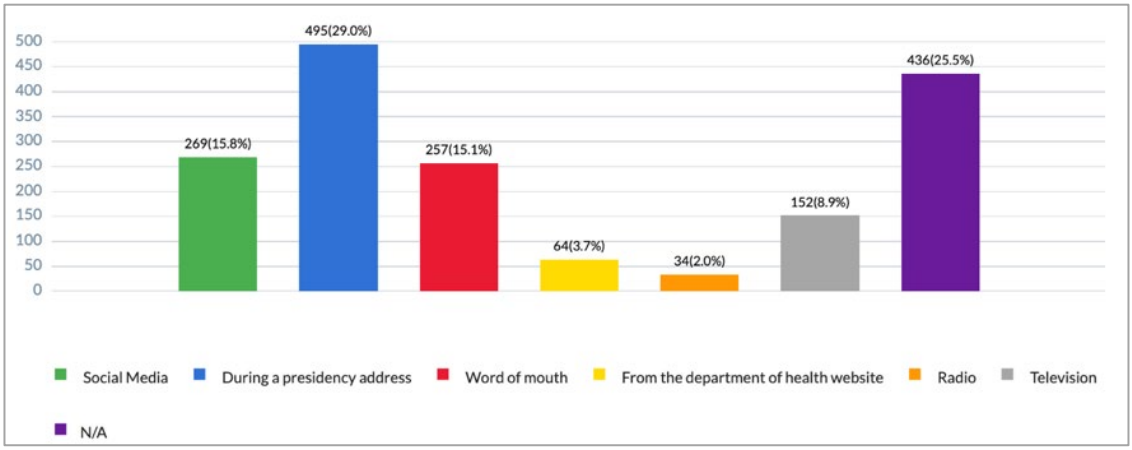


Figure J-21: COVID Alert Survey results – COVID Alert dissemination channel

Figure J-22 shows the beliefs that survey participants have about COVID Alert.

Answer	Count	Percent
The government is using COVID Alert to track my movements	353	5.83%
My personal information is being stored on the app	389	6.42%
COVID Alert can only access my Bluetooth	480	7.92%
COVID Alert is not able to identify my location	222	3.67%
COVID Alert is accessing my contacts	260	4.29%
COVID Alert uses my location to determine whether I have been in contact with a COVID positive person	1009	16.66%
My identity is protected on COVID Alert	617	10.19%
COVID Alert will notify me if I have been in close contact with someone who tested positive for COVID-19	1162	19.18%
I can use COVID Alert to anonymously alert others if I have tested positive for COVID-19	935	15.44%
I have to enter my personal details if I test positive for COVID and want to alert my contacts	291	4.80%
My data is being collected and sold to third parties	256	4.23%
Other (please specify):	83	1.37%

Figure J-22: COVID Alert Survey results – beliefs

Figure J-23 shows the endorsements that would (or have) influenced the survey participants to download COVID Alert.

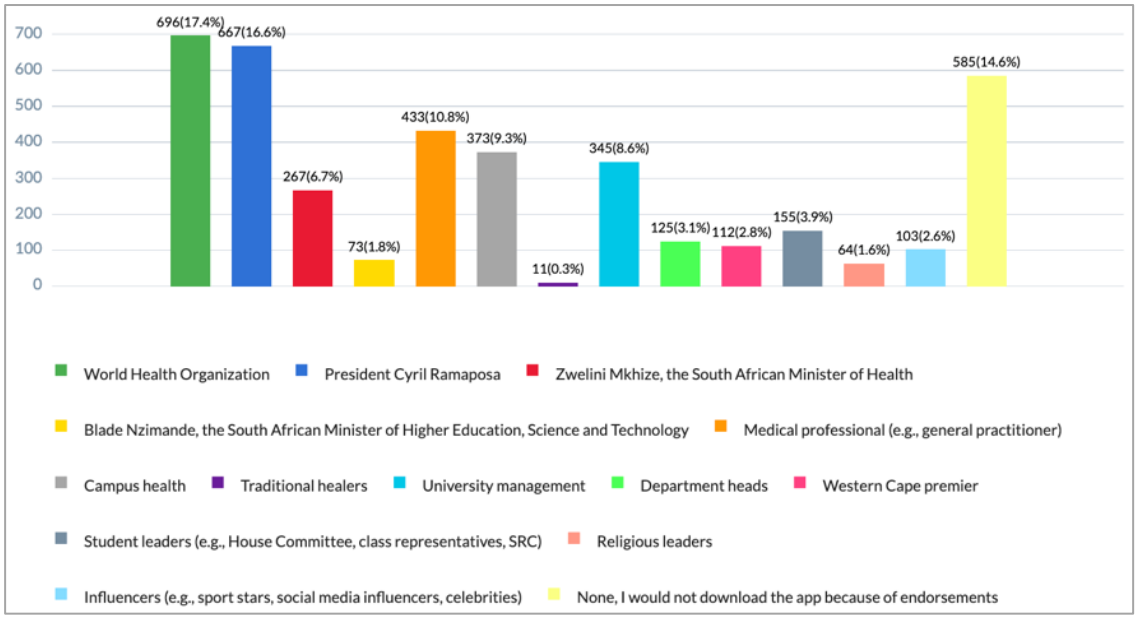


Figure J-23: COVID Alert Survey results – influences of endorsements on COVID Alert

Figure J-24 shows the motivations that survey participants have to use COVID Alert.

Answer	Count	Percent
I have an elevated risk if I contract COVID, I want to know about any potential exposures	299	4.41%
People I stay with have an elevated risk if they contract COVID, I don't want them to get it from me	581	8.57%
I feel more in control knowing whether I have been in contact with a positive COVID	746	11.01%
I feel a sense of responsibility to protect my community	902	13.31%
I want to do my part in flattening the curve and stopping the transmission of COVID in South Africa	894	13.19%
The majority of people in my social circle have COVID Alert	85	1.25%
I want to do whatever I can to reduce the burden of COVID on our healthcare facilities	747	11.02%
I do not want to go into a hard lockdown again	775	11.43%
I want to be able to finish my studies in person	753	11.11%
Without a vaccine being available to the broader population any time soon, we need to adhere to all non-pharmaceutical interventions	656	9.68%
N/A - there are no motivations for me to use the App	340	5.02%

Figure J-24: COVID Alert Survey results – COVID Alert motivations

Figure J-25 shows the motivations that make survey participants sceptical or hesitant to use COVID Alert.

Answer	Count	Percent
The App infringes on my basic rights	189	6.32%
I value my privacy and the app is probably tracking my location or storing my personal information	685	22.91%
I don't want to use my data to download the app	157	5.25%
I don't have enough memory on my phone	258	8.63%
I don't want the app to use my cell phone data in the background	387	12.94%
COVID does not exist, it is a conspiracy	15	0.50%
It is unlikely that I would catch the virus	49	1.64%
Prayers and religious rituals will protect me from the virus, I do not need COVID Alert	30	1.00%
I don't trust the messages the government is providing about the pandemic	190	6.35%
I don't think this pandemic is that serious	40	1.34%
The government is over exaggerating the pandemics impact	58	1.94%
There is no need for an app, paper-based contact tracing works fine	43	1.44%
I have already had COVID-19 and can't get it again – I don't need the App	25	0.84%
I don't care if I get COVID	52	1.74%
I don't want to know if I have been in contact with a COVID positive person, I don't want to be fearful	120	4.01%
I don't need to practice non-pharmaceutical interventions anymore – the vaccine is coming	15	0.50%
N/A - I am not hesitant or skeptical to use the App	677	22.64%

Figure J-25: COVID Alert Survey results – COVID Alert hesitancy