The Development of a Telemedicine Service Maturity Model

by

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

December 2013

Abstract

A telemedicine service is a healthcare service *(-medicine)* that is delivered over a distance *(tele-)*. The interest in the potential of telemedicine to increase the quality, accessibility, utilization, efficiency and effectiveness of healthcare services is fuelled by the rapid development of information and communication technology (ICT) and connectivity. Despite this potential, the success rate of telemedicine services disappoints. Many mistakes in the implementation of telemedicine services are repeated over and over again and best practices are not captured and replicated. This study responds to the need for reference models for the assessment and optimization of telemedicine services in a consistent, systematic and systemic way.

Maturity models are reference models that describe typical patterns in the development of organizational capabilities and depict a sequence of stages towards the desired state. Many reference models exist that are applicable to telemedicine services, but none of these provide guidance for the optimization of services, like a maturity model does. Many maturity models exist within a health systems context, but none of these can be applied "as is" to telemedicine services.

In this study an iterative top-down design approach is followed to develop a Telemedicine Service Maturity Model (TMSMM). This model facilitates the assessment of a telemedicine service on micro, meso, and macrolevel along all the domains that comprise the telemedicine health system. Sets of capability statements are defined, which follow each other in a cumulative manner, hence providing a maturation path towards the desired maturity state.

These sets of capability statements provide yardsticks according to which quantitative values are allocated to an intangible concept, such as maturity. Once an individual service is assessed, further actions towards the optimization of the service can be derived from these yardsticks. The multidimensional design of the TMSMM, as well as the fact that capability statements facilitate the consistent quantification of maturity, makes it possible to analyze the aggregated results of cohort of services. To accomplish this, principles of business intelligence and data warehouse design are applied together with online analytic processing (OLAP) procedures.

The TMSMM addresses the previously unfulfilled need for a reference model to assess and optimize telemedicine services in a consistent, systematic and systemic way. This study spans several academic and professional domains and thereby contributes to the scientific world of telemedicine and ehealth.

Opsomming

'n Telegeneeskunde diens is 'n gesondheidsdiens (-*geneeskunde*) wat oor 'n afstand gelewer word (*tele*-). Met die snelle ontwikkeling van inligtings-en kommunikasie-tegnologie hou telegeneeskunde die potensiaal in om die kwaliteit, toeganklikheid, benutting, doelmatigheid en doeltreffendheid van gesondheidsdienste te verhoog. Ten spyte van hierdie potensiaal, stel die aantal onsuksesvolle telegeneeskunde dienste teleur. Heelwat foute in die implementering van telegeneeskundedienste word oor en oor gemaak, terwyl die beste praktyke nie vasgevang en herhaal word nie. Hierdie studie is onderneem in reaksie op die behoefte aan 'n verwysingsmodel vir die assessering en optimering van telegeneeskunde dienste op 'n konsekwente, sistematiese en sistemiese manier.

Volwassenheidsmodelle is verwysingsmodelle wat tipiese patrone in die ontwikkeling van organisatoriese vermoeëns beskryf. Dit stip 'n aantal fases neer wat uiteindelik behoort te lei na die ideale organisatoriese toestand. Daar bestaan verskeie verwysingsmodelle wat van toepassing is op telegeneeskunde dienste, maar geeneen daarvan gee leiding met die oog op die optimering van die diens, soos in die geval van 'n volwassenheidsmodel nie.

In hierdie studie word 'n iteratiewe van-bo-na-onder ontwerpsbenadering gevolg om 'n telegeneeskunde volwassenheidsmodel (TMSMM) te ontwikkel. Hierdie model fasiliteer die assessering van 'n telegeneeskunde diens op 'n mikro-, meso- en makrovlak en met betrekking to al die fasette waaruit 'n telegeneeskunde stelsel bestaan. 'n Aantal vermoeëstellings is gedefinieer. Hierdie stellings volg op mekaar en akkumuleer om sodoende 'n volwassenheidspad na die verlangde toestand aan te dui.

Hierdie vermoeëstellings verskaf maatstawwe waarvolgens kwantitiewe waardes toegeken kan word aan 'n ontasbare konsep, soos volwassenheid. Sodra 'n individuele diens geassesseer is, kan verdere aksies met die oog op die optimering van die diens afgelei word. Die multidimensionele ontwerp van die TMSMM, tesame met die feit dat die vermoeëstellings volwassenheid op 'n konsekwente manier kwantifiseer, maak dit moontlik dat die data van 'n kohort dienste saamgevoeg kan word met die oog op analise. Beginsels van besigheidsintelligensie, datastoorontwerp asook aanlyn analitiese prosessering (OLAP) word hiervoor ingespan.

Die TMSMM spreek tot die voorheen onvervulde behoefte aan 'n verwysingsmodel waarmee telegeneeskunde dienste geassesseer in geoptimeer word in 'n konsekwente, sistematiese en sistemiese manier. Hierdie studie strek oor verskeie akademiese en professionele domeine en lewer sodoende 'n bydrae tot die multidissiplinêre wetenskapswêreld van telegeeskunde en e-gesondheid.

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Glossary

Capability area: A cluster of related activities, associated with a specific combination of dimensions and spanning all maturity levels.

Capability statement: A generic statement that describes a characteristic of a process as it applies to a specific maturity level.

Dimension: The measurement (of something) in a particular direction.

Domain: A a sphere of activity, concern, or function (Merriam Webster, 2013) and represents an angle from which to view the use, consequences and implications of the entity under consideration.

Maturity model: A maturity model is a reference model, which describes typical patterns in the development of organizational capabilities and usually depicts a sequence of stages toward the desired state. Together, these stages form an anticipated, desired or logical path from an initial to a target maturity state (De Bruin *et al.*, 2005; Solli-Saether and Gottschalk, 2010; Pöppelbuß *et al.*, 2011).

Maturity (organizational context): An organizational design term used to indicate the capability of a process, object or person to respond to circumstances or the environment in an appropriate manner.

Maturity level: The degree of process improvement across a predefined set of areas (Paulk *et al.*, 1993).

(Organizational) maturity: Organizational maturity is an organizational design term used to indicate the capability of a process, object or person to respond to the internal and external organizational environment according to a certain level of maturity.

Reference model: An abstract framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment (OASIS, 2013).

mHealth: Healthcare services enabled by mobile technology.

Process area: A cluster of related activities, associated with a specific maturity level that, when performed together, achieve a set of goals considered important (Bate *et al.*, 1995).

Telemedicine service: : A healthcare service delivered over a distance

Accronyms

ATA American Telemedicine Association

CMM Capability Maturity Model

CMMI Capability Maturity Model Integration

DoH Department of Health

DR Design Requirement

EHR Electronic Health Record

EMR Electronic Medical Record

HIS Hospital Information System

ICT Information and Communication Technology

ISDN Integrated Service

ISfTeH International Society for Telemedicine and eHealth

KDS Khoja-Durrani-Scott

MAST Model for the Assessment of Telemedicine

NIMM NHS Infrastructure Maturity Model

NHLS National Health Laboratory Services

OLAP On-line Analytical Processing

PACS Picture Archiving and Communication System

QMMG Quality Management Maturity Grid

RIS Radiology Information System

RQ Research Question

SATMA South African Telemedicine Association

SEI Software Engineering Institute

SLA Service Level Agreement

SITA State Information Technology Agency

SPC Statistical Process Control

SPICE Software Process Improvement and Capability Determination

TAM Technology Acceptance Model

TMSMM Telemedicine Service Maturity Model

TQM Total Quality Management

UTAUT Unified Theory of Acceptance and Use of Technology

Chapter 1

Introduction

Telemedicine broadly refers to the delivery of healthcare (*medicine*) where distance (*tele*) is an issue. This can entail a simple telephone conversation between a doctor and his patient or a complicated laparoscopic cholesytectomy by a team of surgeons, situated 6000km from the patient (Holt *et al.*, 2004).

Telemedicine has the potential to address diverse problems in modern healthcare by increasing the quality, accessibility, utilization, efficiency and effectiveness of healthcare while reducing costs (Bashshur *et al.*, 2000; Edwards, 2011). Despite such potential, the success rate of telemedicine services is disappointing (Bangert and Doktor, 2003; Broens *et al.*, 2007; Paul *et al.*, 1999). Reasons for this include poor technology performance, organizational issues, financial and legal barriers, as well as resistance to change on the part of all role players (Bashshur *et al.*, 2000; ETHAL, 2008; Paul *et al.*, 1999; Mars, 2011).

The South African National Department of Health (NDoH), in 1998, published a proposal for the establishment of a South African telemedicine system (Government, 1998). This document focusses on the delivery of healthcare over distance to improve the accessibility of specialist healthcare in the rural areas of the country. Since then, a significant amount of telemedicine services have been initiated by the NDoH. Many of these projects were not implemented successfully or did not survive past the pilot phase. In some cases, telemedicine equipment, for example video-conferencing equipment or electronic monitoring devices, are locked in store-rooms, are in need of maintenance, or are being used for a purpose other than the one for which were originally developed for (Mars, 2009; Wynchank and Fortuin, 2012).

Apart from the waste of equipment and human resources, Yellowlees (2005) considers the damage to the reputation of telemedicine an even greater expense. In 2010, the NDoH placed a moratorium on the deployment of new telemedicine services in the South African public health system until the reasons and remedies for failures had been established (Fortuin, 2010). No full scale evaluation study has been conducted since then, but the moratorium does not exist anymore.

In the 2012 – 2017 eHealth Strategy the NDoH acknowledges the initial failure in the setting up and sustaining of telemedicine services. However, the strategy still recognizes the potential of telemedicine as an "enabling tool that could bridge the gap between rural healthcare and specialist facilities".

1.1 Research Problem

A number of international studies (Grigsby *et al.*, 2002; Yellowlees, 2005; Bashshur *et al.*, 2005) have identified the same problems experienced by the NDoH. Broens *et al.* (2007) conducted a systematic review of telemedicine services, published in the *International Journal for Telemedicine and Telecare* to respond to the question of why telemedicine services fail. They found that 75 per cent of successful pilot services did not last.

The problem is, first, that many telemedicine services, which proved to be successful in the pilot phase, are not sustained. But, secondly, an even greater problem is that many mistakes in the implementation of telemedicine services are repeated over and over again. Only a few examples of good practices are replicated. A lack of reference models for telemedicine services also results in a lack of guidelines for the optimization of these services.

1.2 Research Opportunity

By the end of the previous decade, the first telemedicine initiatives of pioneers were taken further with the use of telemedicine applications being adopted for daily healthcare routines (ETHAL, 2008). At the same time many authors, for example Steele (1996), Scott *et al.* (1999) and Hebert (2001), identified the need for general frameworks or methodologies for the evaluation of telemedicine initiatives. The need for models and frameworks for the implementation, evaluation and optimization of ehealth and telemedicine is also echoed throughout the recent eHealth Strategy for South Africa (Government, 2012).

The concept of *health systems strengthening*, as defined by the World Health Organization (WHO, 2013) is "the process of identifying and implementing an array of initiatives towards the improvement of the health system under consideration". Frameworks are not only needed to evaluate the eventual outcomes of the telemedicine services, they are also needed as a guide in their optimization thereof.

The lack of standardized evaluation frameworks may result in early-stage assessments of new initiatives that show significant benefits in some areas, but other important parameters – most often costs – are not considered (Jackson and McClean, 2012). The opposite is also possible, namely that a pilot project is prematurely stopped, because an early-stage assessment of outcomes was made before the service had reached maturity. Standardized frameworks, furthermore, could facilitate meaningful comparisons and analyses of cohorts of services to produce the broad evidence base needed to demonstrate the value of telemedicine services (Scott, 2010).

Two other groups of researchers identified similar research gaps and have recently published valuable contributions in this regard. The development of the model for assessment of telemedicine applications (MAST) by Kidholm *et al.* (2012) is an ongoing research project by the European Commission. Khoja *et al.* (2013*a*) developed a framework to provide "a systematic and comprehensive approach to evaluating e-health initiatives and making it easier to compare".

These two studies serve as confirmation of the need for frameworks that can assess and provide guidelines towards the optimization of telemedicine services. They, together with other existing frameworks, are critically evaluated in Chapter 4 and serve to confirm the unique contribution made by this study.

1.3 Maturity Models: A Possible Solution?

Mettler (2012) explains that maturity models fall within the scope of reference models in that they include reusable and efficient state of the art practices, which constitute a reference for a certain domain. A reference model is thus more than simply a checklist, an assessment methodology or an implementation framework. The Organization for the Advancement of Structured Information Standards' (OASIS, 2013) definition for a *reference model* is quoted below (own emphasis).

> A reference model is an abstract framework for understanding **significant relationships** among the entities of some environment, and for the development of **consistent standards** or specifications supporting that environment. A reference model is based on a **small number of unifying concepts** and may be used as a basis for **education** and **explaining standards to a non-specialist**. A reference model is **not** directly tied to any **standards, technologies or other concrete implementation details**, but it does seek to provide a **common semantics** that can be used unambiguously **across and between different implementations**.

A maturity model is a reference model, which describes typical patterns in the development of organizational capabilities and usually depicts a sequence of stages toward the desired state. Together, these stages form an anticipated, desired or logical path from an initial to a target maturity state (De Bruin *et al.*, 2005; Solli-Saether and Gottschalk, 2010; Pöppelbuß *et al.*, 2011).

A telemedicine maturity model has the potential to address the repeated call for general frameworks or methodologies for the evaluation of the capabilities and outcomes of telemedicine, but also as a guide towards the optimization of telemedicine services.

1.4 Research Hypothesis, Purpose and Objectives

Departing from this research opportunity, the following research hypothesis, purpose and objectives are set:

1.4.1 Research hypothesis

A maturity model for telemedicine services can fulfill the need for a reference model to assess telemedicine services and to guide and educate stakeholders towards the optimization of these services.

1.4.2 Research purpose

The purpose of this study is to either find or develop a maturity model for telemedicine services that can be used to describe and assess telemedicine services as well as to guide and educate stakeholders towards the optimization of these services.

1.4.3 Research objectives

In order to accomplish the research purpose, the following objectives are set:

1. Understand the telemedicine landscape and define concepts and paradigms relevant to this study.
2. Understand the scientific and design considerations of maturity models and define concepts and paradigms relevant to this study.
3. Define design requirements for a telemedicine maturity model.
4. Search for a framework that satisfies all of these requirements.
5. If such a framework cannot be found, develop a maturity model for telemedicine services.
6. Verify that this model does satisfies all the design requirements.
7. Confirm the validity of the research process.

1.5 Research Methodology

> Whereas in everyday life we search for knowledge that will help us cope better with challenges and demands of every day (a very pragmatic interest), the aim of science is to generate truthful (valid and reliable) descriptions, models and theories of the world (Mouton, 2001).

Mouton (2001) explains that any research process fluctuates between two so-called worlds. The world of everyday life encompasses the ordinary and physical reality in which we exist, the ordinary problems we have to solve and the ordinary lessons we learn on a daily basis. The world of science and scientific research takes issues from the world of everyday life and turns these into objects of systematic and rigorous enquiry.

Earlier in this chapter, a problem from the world of everyday life was described: despite the potential that telemedicine services hold, their success rates are disappointing. From the world of science a research gap was identified: there is a need for telemedicine evaluation frameworks and reference models that can be used to assess and guide throughout the life cycle of a service. The concept of a *maturity model* was then introduced as an existing artefact from the world of science that could possibly fill this gap. The research hypothesis was set accordingly.

The four sets of research methods that are used in this study, are indicated in Figure 1.1. It can be seen in this figure that the research methodology is anchored in the world of science (top) as well as the world of everyday life (bottom). The numbers of the research objectives, which are investigated in terms of each of the methods, are indicated in this figure.

Literature study to understand the state of the art (Research objectives 1 and 2): A review of the current scientific literature was conducted in order to find definitions, paradigms, approaches, models and frameworks relevant to this study.

Requirements mapping (Research objectives 3 and 4): The design requirements as derived from the science of maturity models were mapped against the existing models and frameworks concerning telemedicine.

Iterative design process (Research objective 5): The iterative design approach has as input, first, empirical data from the world of everyday life. This is in the form of inputs from telemedicine practitioners and peers as well as application of early versions of telemedicine maturity model to actual services. Second, from the world of science, paradigms, models and frameworks which serve as input to the development of a maturity model for telemedicine services.

Verification and validation (Research objectives 6 and 7): Case studies, expert interviews and peer review yielded empirical data which were drawn from the world of everyday life. Together with the knowledge gained from the world of science, these data are used to verify and validate that the research outcome correlates with existing knowledge from the world of science and contributes new knowledge to this field.

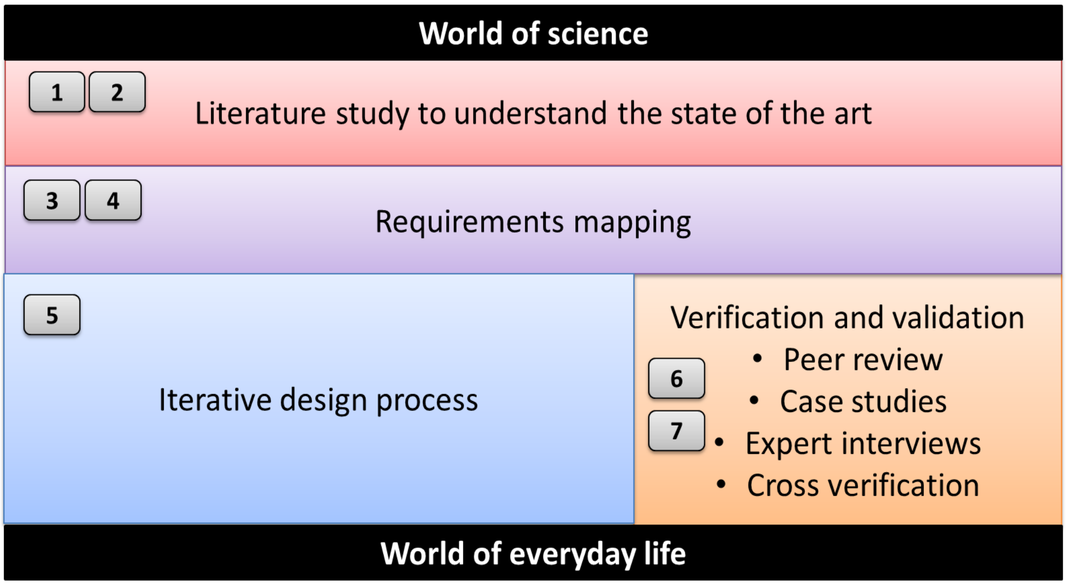

Figure 1.1: Research methods

In the sections that follow, more detail is provided on each research method as well as the relevant research questions and chapters.

1.5.1 Literature study

Table 1.1 shows the research objectives and questions addressed by the literature study. The respective chapters are indicated in the last column of Table 1.1 as well as by the numbered indicators on Figure 1.2.

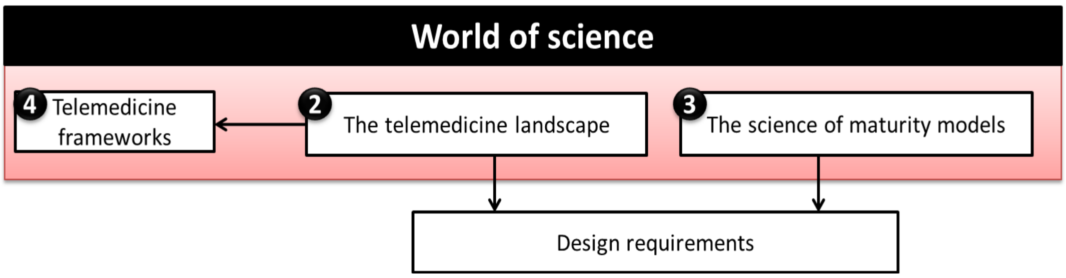

Figure 1.2: Research roadmap: A study of the state of the art

Table 1.1: Objectives and questions addressed by literature study

Research Objectives	Research Questions	Chapter
1 Understand the telemedicine landscape and define concepts and paradigms relevant to this study.	1.1. What are the origins of telemedicine? 1.2. What are the existing definitions, paradigms and trends and applications? 1.3. What are typical telemedicine services?	**2**
2. Understand the science and design considerations of maturity models and define concepts and paradigms relevant to this study.	2.1. What are the origins, existing definitions, paradigms and trends concerning the science of maturity models? 2.2. What maturity models exist? 2.2. What design approaches and requirements are applicable to maturity models?	**3**
3. Define design requirements for a telemedicine maturity model.	3. What are the design requirements a reference model must satisfy so that it can be used to describe and assess telemedicine services and to guide and educate stakeholders towards optimization of these services.	**3**

Two research domains are of concern to this study, namely *telemedicine* and *maturity models*. Existing research literature was studied to understand and describe the paradigms, definitions, theories and research gaps of the research domains as well as current trends and thought processes. This included peer reviewed publications (articles, books, theses, dissertations, position papers) from both domains as well as grey literature (non-peer reviewed internet publications and opinions in the form of discussion fora and commentary pieces). Several local and international conferences on this topic were also attended and addressed.

The state of the art presented in Chapter 2 (*The Telemedicine Landscape*) and Chapter 3 (*Maturity Models*) contain the paradigms, theories and definitions that form the basis of this study. Chapter 3 is concluded with a set of design requirements. These design requirements are based on design considerations taken from the science of maturity models, within the context of the telemedicine landscape.

The next objective was to find a framework which adheres to these requirements.

To this purpose, Chapter 4 critically examines, in terms of design requirements, frameworks that could possibly address the research problem. Selection of the frameworks for inclusion in this chapter, was based on relevance, potential (to address the research problem) as well as quality and authority of the publication.

1.5.2 Requirements mapping

The knowledge gained in terms of telemedicine, telemedicine frameworks and the science of maturity models, was used as input for the requirements mapping phase (refer to Figure 1.3). The design requirements that are defined in Chapter 3, are mapped with exiting telemedicine frameworks in order to answer the research questions outlined in Table 1.2.

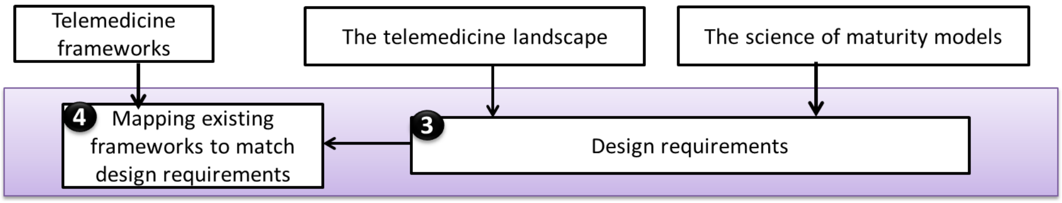

Figure 1.3: Research roadmap: Requirements mapping

Table 1.2: Objectives and questions addressed through requirements mapping

Research Objectives	Research Questions	Chapter 4
4. Search for a framework that satisfies all of these requirements.	4.1. What telemedicine reference models, frameworks or guidelines exist? 4.2. Which design requirements are satisfied by each of the respective frameworks? 4.3. Do any of these frameworks satisfy all the design requirements?	

1.5.3 Iterative design process

Chapter 4 concluded with the notion that no framework exists which is able to satisfy all the design requirements and a new framework thus needs to be developed. This framework is referred to as the Telemedicine Service Maturity Model (TMSMM).

As shown in Figure 1.4, an iterative design process was followed to develop a conceptual model (Chapter 5), capability statements (Chapter 6), and an assessment methodology (Chapter 7). In doing so, research objective 5 is addressed (refer to Table 1.3).

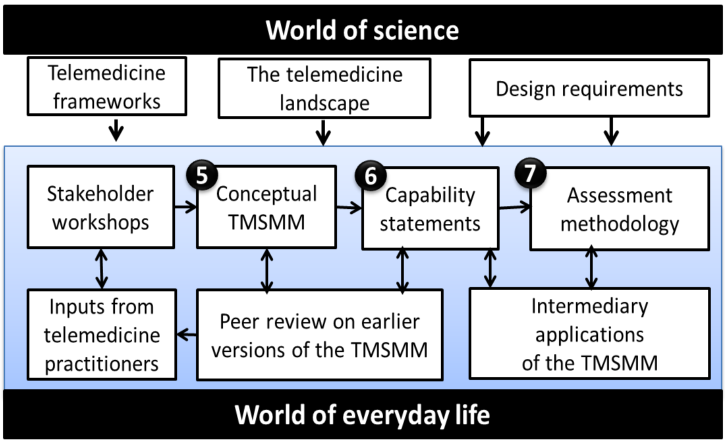

Figure 1.4: Research roadmap: Iterative design process

Table 1.3: Objectives and questions addressed through the iterative design process

Research Objectives	Research Questions	Chapter
		5,6,7
5. Develop a new telemedicine service maturity model (TMSMM).	5.1. How should the conceptual model be designed to address the design requirements? 5.2. How should the capability statements be formulated to address the design requirements? 5.3. How should the service data be captured, stored, aggregated and analyzed to meet the design requirements?	

The scientific approach followed in the development of the TMSMM resembles the frameworks of Solli-Saether and Gottschalk (2010), De Bruin *et al.* (2005) and Von Wangenheim *et al.* (2010). It takes into account the iterative nature of the maturity model development process, as well as the need to combine theoretical and empirical research. Insights from a previous phase (study of the state of the art) serve as input for this iterative design process, together with empirical inputs from telemedicine practitioners, peers and intermediary applications of the TMSMM. The Health Research Ethics Committees of Stellenbosch University as well as the

Western Cape Departement of Health approved the gathering of empirical inputs from telemedicine practioners (refer to Appendix B).

A top-down approach (De Bruin *et al.*, 2005) was followed in that the conceptual model is developed first (Chapter 5) followed by the more detailed capability statements (Chapter 6) and maturity assessment methodology (Chapter 7).

1.5.3.1 Development of the conceptual model

Four research iterations were executed in the development of the conceptual model (Chapter 5). Each iteration starts with a stakeholder workshop and is considered to be complete once the results are peer reviewed and published. The results of each iteration, together with more stakeholder input and new insights concerning the state of the art, are then used as input for the next iteration (refer to Figure 1.4).

1.5.3.2 Development of the capability statements

In Chapter 6 the capability statements are defined within the framework of the conceptual model and also with the design requirements in mind. It also draws upon knowledge concerning the telemedicine landscape and existing frameworks (world of science) as well as information from the world of everyday life, based on the application of early versions of the TMSMM.

1.5.3.3 Assessment methodology

If the purpose of this study was limited to the development of an abstract framework for telemedicine services, then this purpose would have been achieved by the development of the conceptual TMSMM (Chapter 5) and the capability statements of the TMSMM (Chapter 6). However, the purpose also includes confirmation that this model can be used to assess telemedicine services and to guide and educate stakeholders towards the optimization of these services. Therefore, a maturity assessment methodology needed to be developed whereby the TMSMM can be used for this purpose. This is discussed in Chapter 7.

1.5.4 Verification and validation

The objectives and questions relevant to this part of the methodology are indicated in Table 1.4. The concern of the verification process is whether the TMSMM satisfied the initial design requirements.

Leedy and Ormrod (2012) distinguish between internal and external validation. The purpose of internal validation is to ensure that the research process has sufficient controls to ensure that the research outputs are warranted by the research inputs and research process. External validation confirms that the research outputs can be used to make generalizations about the world beyond the research context.

The design requirements for the TMSMM, research questions and research purpose are indicated at the top of Figure 1.5. These elements, from earlier chapters (refer to grey chapter numbers), serve as controls for the verification (Chapter 8), internal validation and external validation (Chapter 9) processes respectively. With these controls in mind, retrospective reviews of the design process and research process are amongst the research methods that are applied in chapters 8 and 9.

Other research methods are indicated on the bottom of Figure 1.5. More detail about the case studies, expert interviews and academic peer review are presented in the respective chapters.

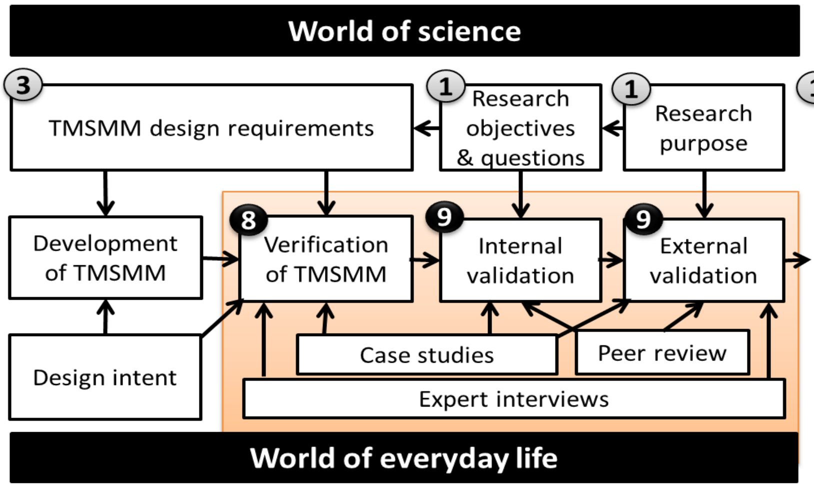

Figure 1.5: Research roadmap: Verification and validation

Table 1.4: TMSMM verification and research validation

Research Objectives	Research Questions	Chapter
6. Verify that this model satisfies all design requirements.	6. Does the model satisfy all design requirements ?	8
7. Validate this research.	7.1. Internal validation: Are the answers to each research question warranted by the research inputs and research process? 7.2. External validation: Is the research purpose accomplished with respect to the world beyond the research context?	9

1.6 Conclusion

The purpose of this study is to either find or develop a maturity model for telemedicine services and then to confirm that this model is indeed a reference model that can be used to assess telemedicine services and to guide and educate stakeholders towards the optimization of these services.

In this chapter, the rationale for the study was presented, as well as a discussion surrounding the appropriate methodology and methods which are proposed to accomplish this end. Table 1.5 shows how these methods relate to each of the research objectives. The number of the chapter in which a specific objective is addressed, is indicated in brackets. This forms the basis of Figure 1.6, the research roadmap.

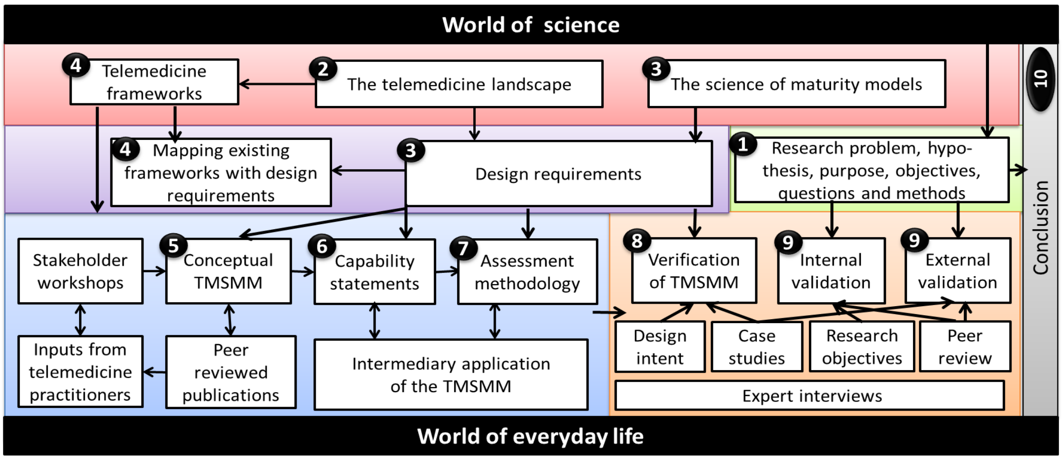

Figure 1.6: Research roadmap for this study

The execution of this methodology is described in the rest of this document, starting in the next chapter with a state of the art study on the telemedicine landscape.

Table 1.5: Research methodology

Research Objectives	Research Questions
1. Understand the telemedicine landscape and define concepts and paradigms relevant to this study. (**Chapter 2**)	1.1. What are the origins of telemedicine? 1.2. What are the existing definitions, paradigms and trends? 1.3. What are typical telemedicine services?
2. Understand the science and design considerations of maturity models and define concepts and paradigms relevant to this study. (**Chapter 3**)	2.1. What are the origin, existing definitions, paradigms and trends concerning the science of maturity models? 2.2. What maturity models exist? 2.3. Which design considerations and approaches are applicable to maturity models?
3. Define design requirements for a telemedicine maturity model. (**Chapter 3**)	3.1. What are the design requirements a reference model must satisfy so that it can be used to describe and assess telemedicine services and to guide and educate stakeholders towards the optimization of these services.
4. Search for a framework that satisfies all of these requirements. (**Chapter 4**)	4.1. What telemedicine reference models, frameworks or guidelines exist? 4.2. Which design requirements are satisfied by each of the respective frameworks? 4.3. Do any of these frameworks satisfy all the design requirements?
5. Develop a new telemedicine service maturity modelf (TMSMM). (**chapters 5,6,7**)	5.1. What conceptual design will address the design requirements? 5.2. Which detail descriptions in terms of capability statements will address the design requirements? 5.3. Which assessment methodology will address the design requirements?
6. Verify that this model satisfies all design requirements. **(Chapter 8)**	6.1. Does the model adhere to each and every design requirement?
7. Validate this research (Leedy and Ormrod, 2012). **(Chapter 9)**	7.1. Internal validation: Are the answers to each research question warranted by the research inputs and research process? 7.2. External validation: Is the research purpose accomplished with respect to the world beyond the research context?

Chapter 2

The Telemedicine Landscape

> Telemedicine is not new, a special discipline of medicine, a new branch of medicine, a technology or a mature discipline. It is unlikely that there is any medical practitioner in South Africa who has not practised telemedicine, albeit unwittingly. (Mars and Jack, 2011)

The landscape of telemedicine is ever-changing to keep pace with rapid development of information and communication technology as well as advancements in clinical practices and processes. It is necessary to first consider the origin and context of telemedicine in order to arrive at a definition for the purposes of this study. The first objective of this study is therefore to understand the telemedicine landscape and define the concepts and paradigms relevant to the study. With this objective in mind, the first three research questions are addressed in this chapter:

Research Question 1.1: What are the origins of telemedicine? (Section 2.1)

Research Question 1.2: What are the existing definitions, paradigms and trends? (Section 2.2)

Research Question 1.3: What are typical telemedicine services? (Section 2.3)

2.1 Origin of Telemedicine

The first mention of the term *telemedicine* in an academic publication was in 1969, when Bird *et al.* as quoted by Bashshur *et al.* (2000) defined telemedicine as the delivery of medical care "without the usual patient confrontation". But telemedicine services existed long before this term was coined. For example, in 1906 results of experiments by a Dutch physician and inventor were published. He recorded - with the help of a string galvanometer and a telephone line - electrical cardiac signals of patients in a hospital 1.5 km away (Strehle and Shabde, 2006).

He called this invention a *telecardiogram*. Moreover, the terms *telognosis, telefluourscopy* and *telediagnosis* were used in academic publications in 1950, 1959 and 1967, respectively (Mars and Jack, 2011).

Stanberry (2000) gives the example of a medical advice service for seafarers in the 1920s as well as the early use of two-way closed circuit television systems to facilitate the transmission of radiographs, medical consultations and other medical images in the 1960s (Grigsby *et al.*, 2002).

In spite of the fact that a significant number of experiments, pilot projects and even full-scale telemedicine service implementations were executed between 1970 and 1993, only a few studies related to telemedicine were published in the academic domain. Findings and conclusions concerning these initiatives were mainly reported retrospectively in academic publications from the mid 1990s.

2.2 Existing Definitions, Paradigms and Trends

Sood *et al.* (2007) executed a systematic literature review in answer to the question "What is Telemedicine?" They included definitions from 104 sources in their study. Two of these definitions were published during the 1970s, 49 definitions appeared between 1993 and 1999, 36 between 2000 and 2007 and 17 of these definitions are undated definitions which are taken from the websites, whitepapers or constitutions of associations concerned with telemedicine.

Most definitions of *telemedicine* are rather context-specific, particularly the earlier definitions which were influenced by the prevalent technology of that time. Some examples are interactive audio-video communication system (Bird,1971) as quoted by Sood *et al.* (2007) the internet (Maheu *et al.*, 2001), images, voice and other data (Grigsby *et al.*, 1998) and video-conferencing (Whitten and Collins, 1997). Other definitions are limited to a specific research discipline, for example medical informatics (Krol, 1997) biomedicine technology (Sood *et al.*, 2007) or biomedical engineering.

It is also noteworthy that some authors who published repeatedly on the topic of telemedicine, redefined their definitions of *telemedicine* in follow-up publications, for example Bashshur (1995); Bashshur *et al.* (1997); Bashshur and Shannon (2009) as well as Grigsby *et al.* (1998, 2002). This is possibly an indication of the the fact that this field of study is still evolving.

In the case of the TMSMM, it is a reference model and therefore should not "directly tied to any standards, technologies or other concrete implementation details" (OASIS, 2013). Thus, the broad definition of telemedicine as healthcare services delivered over a distance is used throughout this study.

2.2.1 Telemedicine as an academic discipline

The fact that telemedicine is linked to a number of associations, education centres and journals bears out its status as an established and well researched academic domain. The American Telemedicine Association (ATA), which was established in 1993, is possibly the oldest association to be primarily concerned with telemedicine. Other associations included in the study by Sood *et al.* (2007) are the Association for Telehealth Service Providers, the Swiss Telemedicine Association, the Telemedicine and eHealth Information Service, UK, and the European Health Telematics Observatory.

Other associations not listed by Sood *et al.* (2007), include the Canadian Society of Telehealth and the International Society for Telemedicine and eHealth (ISfTeH) (AMDTelemedicine, 2013). Research and education centres elsewhere in the world include the Norwegian Centre for Telemedicine, the PAN Asian Collaboration for Evidence-based eHealth Adoption and Application as well as the mHealth Alliance. Academic journals on telemedicine include the Journal for Telemedicine and Telecare, the International Journal for Telemedicine and eHealth and the International Journal of Telemedicine and Applications.

In South Africa, an academic Telemedicine Department has been established at the University of KwaZulu-Natal and the South African Telemedicine Association (SATMA) was established in 2011.

2.2.2 The impact of technology on the evolution of telemedicine

In this study, telemedicine is defined as *healthcare services delivered over a distance* but does not imply the use of any specific technology. A telephone conversation between a doctor and his patient can be considered to be telemedicine. In contrast to this simple technology some examples of telemedicine services literally involve cutting edge technology. For example in 2001 a team of surgeons, situated in New York City, removed the galbladder (laparoscopic cholesytectomy) from a woman, 6000km away in Strasbourg (Holt *et al.*, 2004). Many successful telesurgery services followed in the footsteps of this successful operation.

There is a definite relation between the evolution of telemedicine and the evolution of technology. According to Bashshur *et al.* (2000) "telemedicine is a product of the information age, just as the assembly line was the product of the industrial age". To support his statement Bashshur *et al.* (2000) distinguish between three technological eras, namely the telecommunications era, the digital era and the Internet era.

2.2.2.1 Telecommunications era

The so-called telecommunications era spanned the 1970s and continued into the early 1980s. This era depended on broadcast and television technologies, which comprised complex, cumbersome, and often unreliable communication systems. Telemedicine services were not integrated with any other clinical data. Telemedicine programs during the first era often ended as governments terminated the funding before these programs had matured.

2.2.2.2 Digital era

The second era of telemedicine (late 1980s to 1990s) was characterized by the integration of telecommunications and computer processing coupled with transmission of relatively large amounts of information on limited bandwidth. The transmission of data was supported by various communication mediums ranging from telephone lines to integrated service digital network (ISDN) lines. The high costs associated with higher bandwidth became a considerable challenge (Olla, 2007).

2.2.2.3 Internet era

The Internet allows access to a global-communication environment with technology becoming increasingly affordable and available to a growing number of people (Bashshur *et al.*, 2000). The enhanced speed and quality offered by Internet or 3G mobile telephony is providing a host of new opportunities in telemedicine (Olla, 2007).

2.2.2.4 Era of ubiquitous technology

Olla (2007) proposed a fourth era, which is characterized by the use of Internet protocol (IP) technologies, ubiquitous networks, and mobile and wireless networking capabilities.

2.2.3 Telemedicine service contexts

Many authors consider telemedicine to be an answer to the problem of healthcare delivery to underprivileged and under-resourced rural areas and have defined telemedicine accordingly (Perednia and Brown, 1995; Yellowlees, 1997; Higa *et al.*, 1997; LaMay, 1997). It is significant that these definitions were published at the same time that the first telemedicine strategy was proposed by the South African National Department of Health (Government, 1998) as it represents the paradigm within which this strategy was developed. The delivery of healthcare to underprivileged rural areas is a cornerstone of this strategy, as well as the 2012 to 2017 eHealth Strategy (Government, 2012).

Other contexts, especially within the developed world, include home-based healthcare, rehabilitation, emergency/acute and patient self management.

This study originated from a practical problem in the South African public health care system where many of the stakeholders involved in the development and validation of the TMSMM are involved in this system. However, the problem is universal and the reference model should be applicable to telemedicine services within any context.

2.2.4 Telemedicine, ehealth, telehealth, telecare and mhealth

Figure 2.1 is a combination of frameworks from the TeleSCoPE project and the European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (Rudel *et al.*, 2011). The concepts shown in this figure are often used interchangeably. To appreciate the specific position of *telemedicine*, as it is viewed for purposes of this study, the meanings of related concepts are considered in this section.

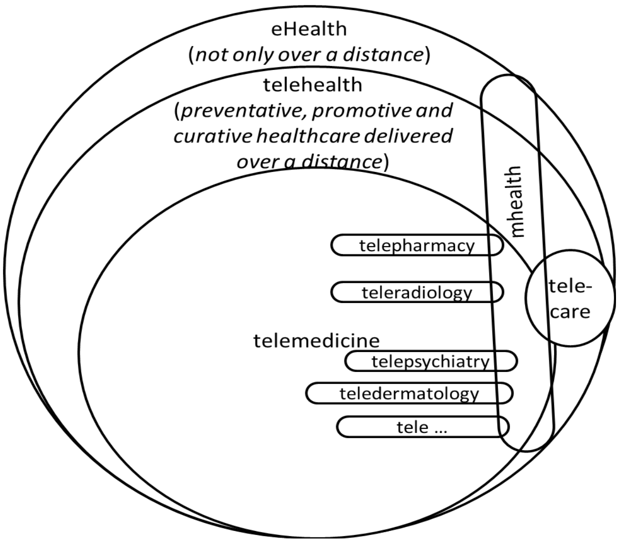

Figure 2.1: Telemedicine, ehealth, telehealth, telecare and mhealth

2.2.4.1 Telehealth

Bashshur *et al.* (2011) explain that telehealth relates to telemedicine the same way as health relates to medicine. Sood *et al.* (2007) considered 104 peer reviewed definitions for telemedicine and then concluded that telemedicine is a subset of telehealth. According to Bashshur *et al.* (2011), Bennet *et al.* coined the term *telehealth* in 1978 to extend the scope of telemedicine by incorporating a "broader set of activities, including patient and provider education".

The notion that telemedicine is a subset of telehealth (Sood *et al.*, 2007; Bashshur *et al.*, 2011) is supported by the community who maintains the telehealth wikipage (Telehealth, 2012). According to them telehealth is an expansion of telemedicine, and unlike telemedicine, which more narrowly focusses on the curative aspect, it encompasses the preventative, promotive and curative aspects of the field.

2.2.4.2 Telecare

According to the Telecare Aware Group (TelecareAware, 2013), "telecare is the continuous, automatic and remote monitoring of real time emergencies and lifestyle changes over time in order to manage the risks associated with independent living." As a preventative health application, it is thus within the scope of telehealth, but not telemedicine.

2.2.4.3 eHealth

The terms *ehealth* and *telehealth* are most often used interchangeably. Semantically the difference between these two concepts is that ehealth applications are not limited to healthcare over a distance, as is the case with telehealth. This distinction is maintained in this study.

2.2.4.4 mHealth

mHealth refers to ehealth applications which are executed with the help of mobile technology. The concept *mhealth* appeared relatively recently on the ehealth scene (Istepanian *et al.*, 2006) and is confirmed by the Google search trends, as shown by Figure 2.2.

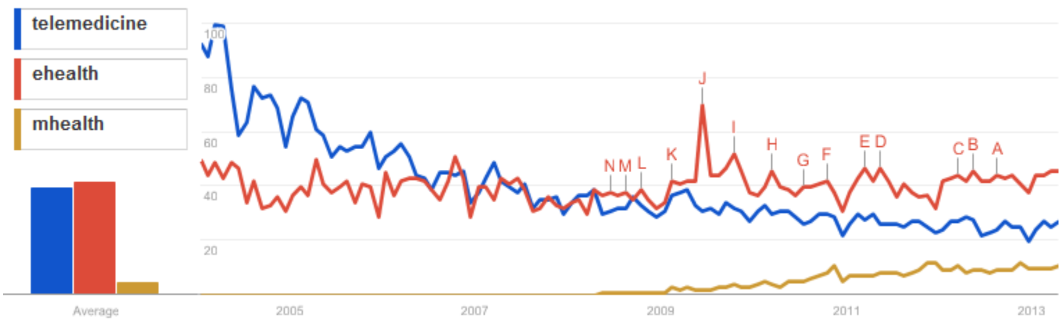

Figure 2.2: Google search trends concerning telemedicine, ehealth and mhealth

In the Telemedicine Hype Cycle Report by the Gartner group, Handler (2012) is critical of what he calls the "over-excitement" surrounding mhealth. He considers the term to be obsolete, because mobile technologies are now routinely incorporated into the delivery of healthcare. Bashshur *et al.* (2011) also draw attention to the fact that mhealth is the only ICT-based health domain justified solely on the basis of mobility and related technology. Despite their doubts that mhealth is conceptually and empirically differentiated from telemedicine, they incorporate mhealth in their *Taxonomies of Telemedicine* due to the wide adoption of the terminology.

For the purposes of this study, mhealth is considered to be a subcategory of ehealth, telehealth or telemedicine, cutting across these categories, as shown in Figure 2.1. The emphasis is on the means (mobile technologies) and not necessarily the end (healthcare delivery) (Edwards, 2011). Since reference models, such as the one relevant to this study, are not tied to any specific technology, no distinction is made between mhealth and non-mhealth in this document.

2.2.5 Service delivery mode

Most publications distinguish between two categories of telemedicine services:

Store-and-forward (or asynchronous) telemedicine services involve the transmission of medical data from a patient to a doctor, or from one healthcare worker to another, for assessment at a later time.

Real-time (or synchronous or interactive) telemedicine services use technology such as video-conferencing and telephones for real-time remote communication.

It is also possible that one telemedicine service has a store-and-forward as well as a realtime component.

A third category has been added in recent publications (Cochrane, 2013; Ramos, 2010), namely **remote monitoring**, which is primarily used for the management of chronic diseases or rehabilitation processes. The recent growth in telemedicine services related to remote monitoring can possibly be linked to the fourth technology era, which was added in Section 2.2.2, namely the era of of ubiquitous technology, as well as the attention given to mhealth applications in the past few years.

2.3 Telemedicine Specializations

Like specializations in the health services, various references to telemedicine specializations can be found, for example teleradiology, teledermatology and telepsychiatry. It may be argued that there are as many telemedicine specializations as actual health science specializations. However, certain health services are more frequently delivered by means of telemedicine, than others. This led to the next research question:

Research Question 1.3: What are typical telemedicine services?

2.3.1 Methodology to identify telespecializations

For the purposes of this study, three different analyses were used to identify the typical telemedicine applications: (1) Gartner group's Telemedicine Hype Cycle, (2) Google's search trends and (3) a statistical topic analysis (STA) of publications from the *Journal for Telemedicine and Telecare* as well as the *International Journal for Telemedicine and eHealth* (Van Dyk, 2010).

2.3.1.1 Gartner Group's Telemedicine Hype Cycle

The Gartner Group periodically compiles reports on Technology Hype Cycles (Edwards *et al.*, 2008; Fenn *et al.*, 2009, 2000; Edwards, 2011; Handler, 2012) in which they differentiate between different telemedicine applications in terms of the so-called technology hype associated with each. This Hype Cycle is shown in Figure 2.3. This curve shows the relationship between expectations on the vertical axis and time (years to mainstream adoption) on the horizontal axis.

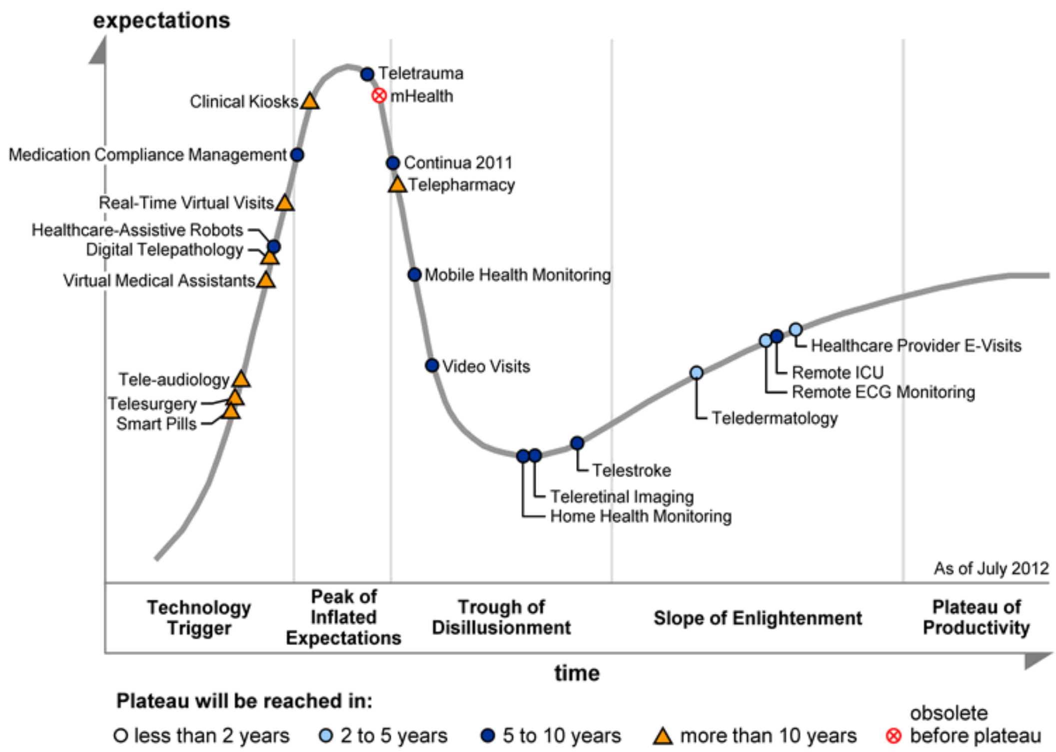

Figure 2.3: The Telemedicine Hype Cycle for 2012 (Handler, 2012)

2.3.1.2 Statistical topic analysis

Van Dyk (2010) used the technique of statistical topic analysis (STA) to identify trends and themes with respect to *telemedicine* (Appendix A.2.1). A total of 651 papers from the *Journal of Telemedicine and Telecare* (September 2013 - June 2010) as well as 1121 papers from the *Journal for Telemedicine and eHealth* were included as a corpus for this study.

A statistical topic model can be used to produce a vocabulary list of all words that appear in the corpus. All telemedicine specializations that were found in this vocabulary list are indicated in Figure 2.4. The x-axis of this figure indicates how frequently a specific terminology appears in the vocabulary of the corpus.

2.3.1.3 Google search trends

Whereas the STA indicates the frequency of vocabularly in the corpus of academic articles, Google search trends indicate how frequently a certain term is entered as a Google search term (Google, 2013). The Google search trend graph shows how often a particular search-term is entered relative to the total search volume in various languages and across diverse regions of the world.

Although, the intent of Google Inc. was probably not to produce an academic research tool, it is used, amongst others, as a research method (Preis *et al.*, 2013; Ball, 2013). Within the context of market competition in the internet industry, it is possible that in a few years, another search engine will surpass Google. However, information about search frequencies will remain relevant trend indicators.

2.3.1.4 Frequency clusters

The y-axis of Figure 2.4 indicates the relative frequency of the above-mentioned vocabulary, in terms of Google search trends. By combining the results of these two analyses in one figure, two clusters of telemedicine specializations can be derived, namely the cluster of low frequency specializations (Figure 2.4) and the high frequency specializations (top right corner):

High Frequency Telemedicine Specializations: teleradiology, telemonitoring, telesurgery, telepharmacy, telepathology, telepsychiatry, teledermatology and telerehabilitation

Lower Frequency Telemedicine Specializations: telestroke, telementoring, tele-ophthalmology, tele-audiology, teleconsultation, tele-oncology, telecardiology, tele-ultrasound

Unlike the other types of telemedicine services in the high frequency cluster, *telemonitoring* and *telerehabilitation* are not linked to a specific clinical specialization.

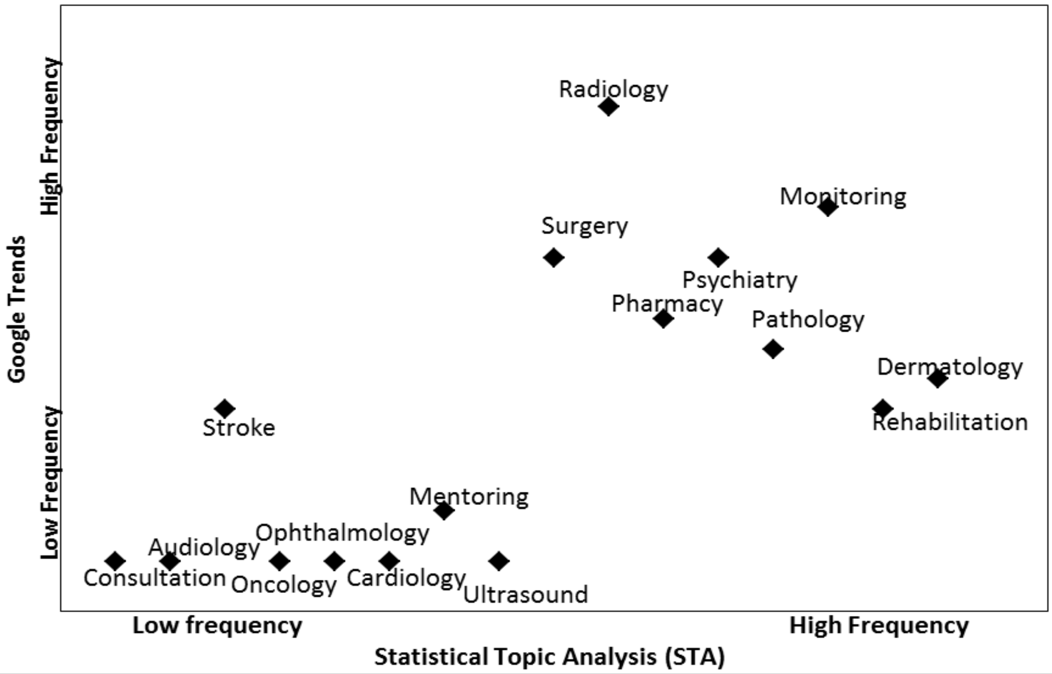

Figure 2.4: Clinical specializations with telemedicine application: Frequency analysis

Instead, they relate to remote monitoring, which is added as third mode of telemedicine service delivery in recent publications (refer to Section 2.2.5). Mobile health monitoring and home health monitoring (trough of disillusionment) as well as remote ECG monitoring and remote ICU monitoring (slope of enlightment), are identified in Gartner's Hype Cycle Handler (2012) as technology drivers for telemonitoring.

The Google trends graph for the five clinical telemedicine specializations with the highest frequency is shown in Figure 2.5. In Figure 2.6 *teleradiology* has been excluded so that the trends of the other high frequency specializations are more clearly visible.

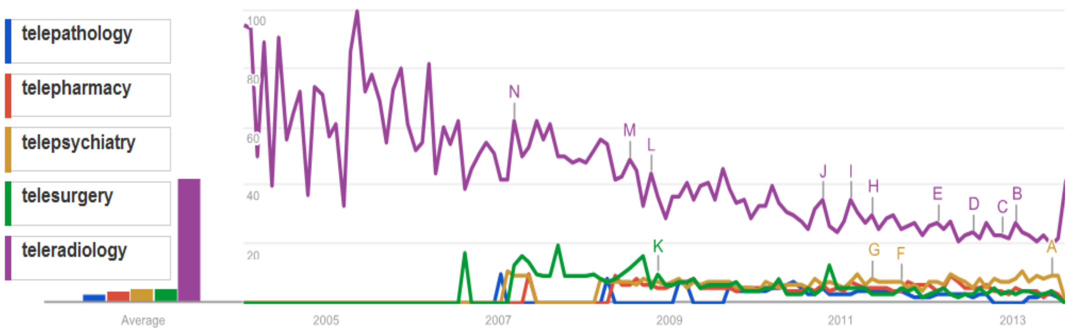

Figure 2.5: Google trends for five high frequency telemedicine specializations

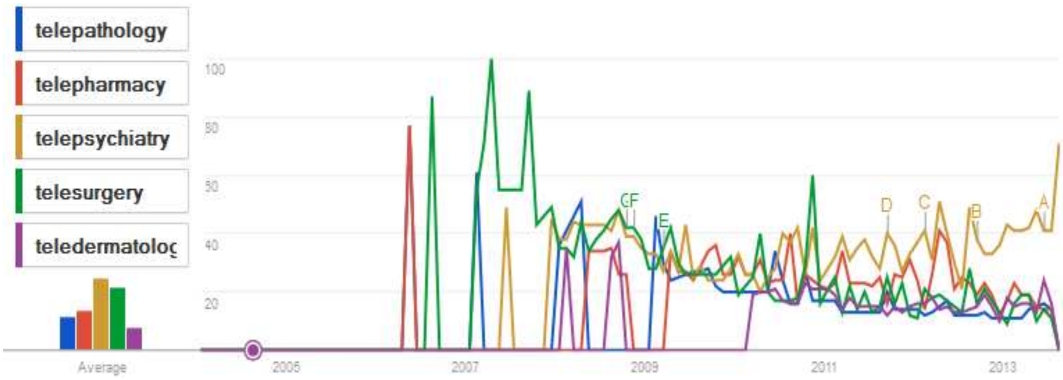

Figure 2.6: Google trends for five high frequency telemedicine specializations (teleradiology excluded)

The remainder of this chapter is structured around these clusters. A detailed discussion is provided on each of the high frequency clinical specializations. The position of these are considered in terms of the Google trends, the STA as well relevant technology from Gartner's group Hype Cycle. Furthermore, some international as well as South African examples and practices are highlighted.

2.3.2 High frequency telemedicine specializations

Each of the telemedicine specializations that appears in the top-right section of Figure 2.4 are elaborated upon in this section.

2.3.2.1 Teleradiology

Of all the telemedicine specializations, teleradiology applications are the most often successfully integrated into health systems (Grigsby *et al.*, 2002). Teleradiology has been adopted as standard clinical practice, to such an extent that it does not even appear on the Telemedicine Hype Cycle (Figure 2.3). The *Journal of Telemedicine and eHealth* use the term *radiology* much more often than *teleradiology*, which could explain the reason why the STA indicated a lower frequency for the use of the term *(teleradiology)* than was expected.

Teleradiology is already used routinely in many European healthcare institutions. More advanced examples of teleradiology involve a Picture Archiving and Communication System (PACS). Here the radiological image, associated with an electronic health record, is stored on a central database, This information can then be viewed and shared by radiographers, radiologists and other clinicians, irrespective of the location of users.

In South Africa, most private hospital groups and some public hospital networks have fully functional teleradiological services. Within the private health sector, PACSs are fully integrated into the hospital information system as well as the information systems of medical insurers. In some areas of the South African public health system, teleradiology services run successfully on a PACS, in others, less sophisticated teleradiology services may be found, for example[1]:

- "Hard-copy" radiological images (e.g. x-rays) are taken, digitized by means of a scanner, and then uploaded to a PACS.
- "Hard-copy" radiological images (e.g. x-rays) are taken, digitized by means of a scanner, and then e-mailed to a specialist. The image is not archived.
- Medical officers take digital pictures of the "hard-copy" radiological image and then SMS this image to a specialist.

2.3.2.2 Teledermatology

Like teleradiology, teledermatology is also well suited for telemedicine, since it relies to a large extent on visual information for diagnosis. According to the STA, the term *teledermatology* appears most frequent in the corpus of articles included in this study. However, the average number of Google searches for *teledermatology* is less than for teleradiology, telesurgery, telemonitoring and telepsychiatry. Handler (2012) nonetheless, positioned it on the slope of enlightenment of the Hype Cycle.

Handler (2012) explains that there are two primary models of teledermatology as well as a hybrid between these two. The first comprises images that are transmitted asynchronously. In the second, synchronous video consultations are used. With the hybrid model high quality images are forwarded to the dermatologist before a video-consultation with the patient. According to Whited (2010) asynchronous teledermatology is cost effective, while video-based teledermatology is not.

Krupinski *et al.* (2008) found that teledermatology consultations are as reliable and accurate as face-to-face consultations. They also found that patients and clinicians are moderately satisfied with teledermatology and that it significantly reduces the health care delivery lead times. This was confirmed by VanDerHeijden (2010) who found that in the Netherlands, the average specialist response time is 5 hours, while it could take 4 to 12 weeks to get an appointment for a face-to-face consultation.

To identify features that contributed to a service becoming standard practice, Finch *et al.* (2006) studied 12 dermatology services within the British National Health System (NHS) that did or did not become part of routine healthcare practice. The successful services were mostly based on store-and-forward technology and involved communication between a nurse or general practitioner (GP) and a specialist.

[1]Examples of teleradiology services are described in more detail in Appendix D. Section D.1.2 describes a teleradiology service within context of the private healthcare system of South Africa. Section D.2 is a cohort analysis of some teleradiology services in South Africa. These case studies are used (amongst others) to verify and validate the output of this study.

Colven *et al.* (2011) describe a Cape Town-based teledermatology service in which primary care providers were equipped with technology and training to take dermatology images and forward these to a dermatologist based at a tertiary hospital. The system also allowed the dermatologist to send back his diagnostic opinion after reviewing the image. Only asynchronous teledermatology services were found in South Africa[2].

2.3.2.3 Telepathology

In certain surgical operations – usually when there is a suspicion of malignant recurrence – a part of the intra-operatively removed tissue is examined by the clinical pathologist during an operation. It is essential that results are promptly available, within the operation time frame, so if no pathologist is available on site, specialist opinion can be obtained through telepathology. Typically the pathologist controls the commands for the microscope and the images are transferred in real-time (ETHAL, 2008).

Two recent technological advancements lead to the development of so-called digital telepathology (indicated in Figure 2.3 as a technology trigger). These advancements are the development of software that includes diagnostic algorithms for automated image analysis as well as more rapid slide-scanning techniques (Handler, 2012). Schools of Medicine are particularly interested in digital telepathology, since it facilitates consultations, second opinions and training.

Banach *et al.* (2008) describe a successful pilot project in South Africa in which three pathology microscopes were installed in Mthatha, East London and Port Elizabeth. These microscopes are connected to the server of the National Health Laboratory Services (NHLS). Images (pathology slides) from the microscopes can be viewed from any computer connected to the NHLS. This service has been improved since 2008 and is still operational.

2.3.2.4 Telepharmacy

Handler (2012) identified three modes of telepharmacy services. First, a pharmacy assistant is able to remotely consult with a pharmacist before dispensing medication. Secondly, a pharmacist can log onto an EHR system and remotely sign off medications. Lastly, a vending machine is able to dispense drugs directly to a patient.

As far as could be established, no official telepharmacy service is currently running in South Africa. There is, however, a high probability that conventional pharmacy services are now being supported by ICT to the extent that the service can be defined as a telepharmacy service.

[2] Some of the telemedicine examples listed in Appendix D.1 are teledermatology services.

2.3.2.5 Telesurgery

Surgical procedures carried out remotely with the assistance of robotic devices and a real-time video and audio connection (Rudel *et al.*, 2011) are referred to as telesurgery. The surgeon is not at the patient's immediate side: visualization and manipulation are performed using tele-electronic devices (Stanberry, 2000). Telesurgery is considered as a technology trigger on the Hype Cycle.

2.3.2.6 Telepsychiatry

Telepsychiatry primarily makes use of video-conferencing technology to provide psychiatric services to patients living in remote locations or otherwise inaccessible areas like psychiatric services in correctional facilities (The American Psychiatric Association, 2013). It is also effective in cases where a second opinion is needed. Not only does it enhance access to services, but it also provides the opportunity for collaboration between professionals who work with the same patient.

Telepsychiatry does not appear on Gartner's Telemedicine Hype Cycle per se, but it is primarily executed by means of video-conferencing. So-called video-visits appear on the trough of disillusionment of the Hype Cycle.

In South Africa Chipps and Mars (2012), Chipps *et al.* (2012*a*) and Chipps *et al.* (2012*b*) conducted extensive development work and research in KwaZulu Natal. They developed a model for the implementation of telepsychiatry services in a resource constrained environment.

2.3.3 Lower frequency specializations

The telemedicine specializations that are discussed in this section are from the lower frequency cluster of Figure 2.4 (bottom-left corner).

2.3.3.1 Telestroke

Telestroke services enable hospitals to get their patients assessed at short notice by a remotely located neurologist. Four out of five strokes are ischemic strokes and it is therefore critical that a neurologist is consulted within the first three hours of such a stroke in order to advise on the administering of a clot-busting drug. Such drugs can minimize disability resulting from the stroke, but can also cause bleeding on the brain (Handler, 2012). Since this is an acute service, synchronous consultation is essential.

2.3.3.2 Tele-ophthalmology

Handler (2012) included *teleretinal imaging* on Gartner's Telemedicine Hype Cycle. This is the use of store-and-forward imaging to remotely diagnose diseases of the retina, especially diabetic retinopathy.

Blanckenberg *et al.* (2011) developed a low cost mobile phone-based ophthalmoscope, which was proven to be clinically effective for retinal examinations to manage both hypertensive and diabetic retinopathy. The developers had the low income communities in Cape Town in mind when they developed this ophthalmoscope. This case is also elaborated upon in Appendix D.1.1.

2.3.3.3 Tele-audiology

The field of audiology encompasses prevention, assessment and rehabilitation. This is accomplished through (1) screening, (2) diagnosis and (3) intervention. Swanepoel and Hall III (2010) give examples of tele-audiology with respect to all three of these service delivery modes.

Typical tele-audiology diagnostic procedures of audiometry, video otoscopy, otoacoustic emissions and auditory brainstem response, produce results that are clinically equivalent to face-to-face versions. Swanepoel and Hall III (2010) found only two examples of tele-audiology interventions, namely hearing aid verification and internet-based treatment for tinnitus. In both these cases the reliability and effectiveness of tele-audiology were demonstrated, however, the cost-effectiveness of tele-audiology has not yet been determined.

2.3.3.4 Teleconsultation

Like telemonitoring and telerehabilitation, teleconsultation does not refer to a particular clinical specialization. A telephone call between two healthcare workers or between a doctor and a patient is per definition a teleconsultation. The most commonly used technology for teleconsultation is video-conferencing. Technology trends from the Gartner Hype Cycle that relate to teleconsultation are e-visits, video visits, clinical kiosks, real-time virtual visits and virtual medical assistants (Handler, 2012).

2.3.3.5 Tele-oncology

Examples of tele-oncology services are varied and depend on the type of cancer and its treatment. Hazin and Qaddoumi (2010) conducted a systematic review of tele-oncology services and divided them into four categories. Each of these respective categories falls within the scope of previously mentioned telemedicine disciplines and are indicated in brackets:

- Video-conferencing (teleconsultation)
- Virtual telemicroscope (telepathology)
- Robotic telesurgery (telesurgery)
- Multimedia collaboration (combination of teleconsultation and teleradiology)

2.3.3.6 Tele-ultrasound

In its millennium development goals, the United Nations prioritized the improvement of maternal health in developing countries (Uys and Van Dyk, 2011). Most tele-ultrasound services are established with this goal in mind. A tele-ultrasound service typically entails the sharing of ultrasound images or image-streams between a primary healthcare provider (e.g. midwife) and a specialist (e.g. gynaecologist). This can either be synchronous or asynchronous.

Uys and Van Dyk (2011) considered the feasibility of a tele-ultrasound system to meet the sonography skills shortage in South Africa. An asynchronous tele-ultrasound service within the context of the Boland Overberg district was found to be feasible in terms of technology, processes, economics and policies. Unfortunately, this service was never implemented.

2.4 Conclusion

The purpose of this study is to either find or develop a maturity model for telemedicine services that can be used to describe and assess telemedicine services and to guide and educate stakeholders towards the optimization of these services. This purpose brings together two research domains, namely *telemedicine* and *maturity models*.

In this chapter, the state of the art of telemedicine was determined. Telemedicine is an established research field and academic discipline, but continuous developments in terms of technology and clinical practice has led to the continuous redefinition and reorganization of telemedicine concepts. In this chapter the current telemedicine landscape was described in terms of the evolution of the concept and origin of telemedicine, technology drivers, the mode of service delivery as well as typical telemedicine specializations.

The next chapter focusses on the state of the art concerning the second research domain, namely maturity models.

Chapter 3

Maturity Models

The purpose of this chapter is to understand the science of maturity models and define concepts and paradigms relevant to this study. In so doing, a design approach and design requirements for a telemedicine service maturity model can be defined. The following three research questions apply:

Research Question 2.1: What are the origins, existing definitions, paradigms and trends concerning the science of maturity models?

Research Question 2.2: What maturity models exist?

Research Question 2.3: Which design approaches and requirements are applicable to maturity models?

Research Question 3: What are the design requirements a reference model must satisfy so that it can be used to describe and assess telemedicine services and guide stakeholders towards the optimization of these services?

3.1 The Origin of Maturity Models

> Science is nothing else but trained and organized common sense, differing from the latter only as a veteran may differ from a raw recruit: and its methods differ from those of common sense only as far as the guardsman's cut and thrust differ from the manner in which a savage wields his club (*Thomas Henry Huxley)*.

This quote was included in an early publication by Nolan and Gibson (1973), describing the so-called stages-of-growth model. Although this initial model has been criticized ever since – even by the author himself – Nolan's attempt to "train and organize common sense" by means of a staged model is acknowledged by many as the inspiration for the development of maturity models (Pöppelbuß *et al.*, 2011; Solli-Saether and Gottschalk, 2010). Nolan (1973) built his theory on the fact that the budget for the ICT life cycle, when plotted over time from initial investment to mature operation, forms an S-shaped curve, yielding three *turnings* which separate four *stages*.

Solli-Saether and Gottschalk (2010) and Pöppelbuß *et al.* (2011) also attribute other multistage models, like the hierarchy of human needs (Maslow, 1943), as well as the theory of economic growth (Kuznets, 1955) to the initial development of maturity models. Soon after Nolan developed his model, Crosby (1979) published a Quality Management Maturity Grid (QMMG) in his book *Quality is Free*, which provided a means for organizations to measure and manage the quality of their processes according to five maturity levels.

3.1.1 Capability maturity model (CMM)

Nolan's and Crosby's respective work served as an inspiration for the maturity model developed by the US Defence Software Engineering Institute (SEI) in the 1980s. In the 1980s, US military projects involving software contractors either ran over-budget or were completed, if at all, far later than planned. A process maturity framework was thus developed to aid in capability evaluation as part of the contract awarding process of the software contractors, which became known as the capability maturity model (CMM).

The introduction of the CMM is considered to be a trigger for the development and adoption of other maturity models (Pöppelbuß *et al.*, 2011; De Bruin *et al.*, 2005; Mettler, 2011). Although the CMM comes from the field of software development, it is also used as a general model to aid in business processes.

The SEI has since created six maturity models, of which three legacy models are now incorporated into one Capability Maturity Model Integration (CMMI). The CMMs and CMMI also serve as a compliance standard (De Bruin *et al.*, 2005). The Capability Maturity Model (CMM) is a registered service mark of Carnegie Mellon University (Bate *et al.*, 1995).

3.1.2 Other maturity models

Many other models have been developed since: Mettler and Rohner (2009) evaluated and compared 135 maturity models, which were retrieved from the ACM digital library, IEEE Explore, and the AISeL database, in conjunction with the exploration of non-research sources using EBSCOhost. Their analysis of maturity models over a period of time (refer to the dotted line on the primary x-axis of Figure 3.1) indicates an exponential growth in the development of these models. They also indicated on this graph, as matter of reference, when certain of the models from the CMM-family, were introduced.

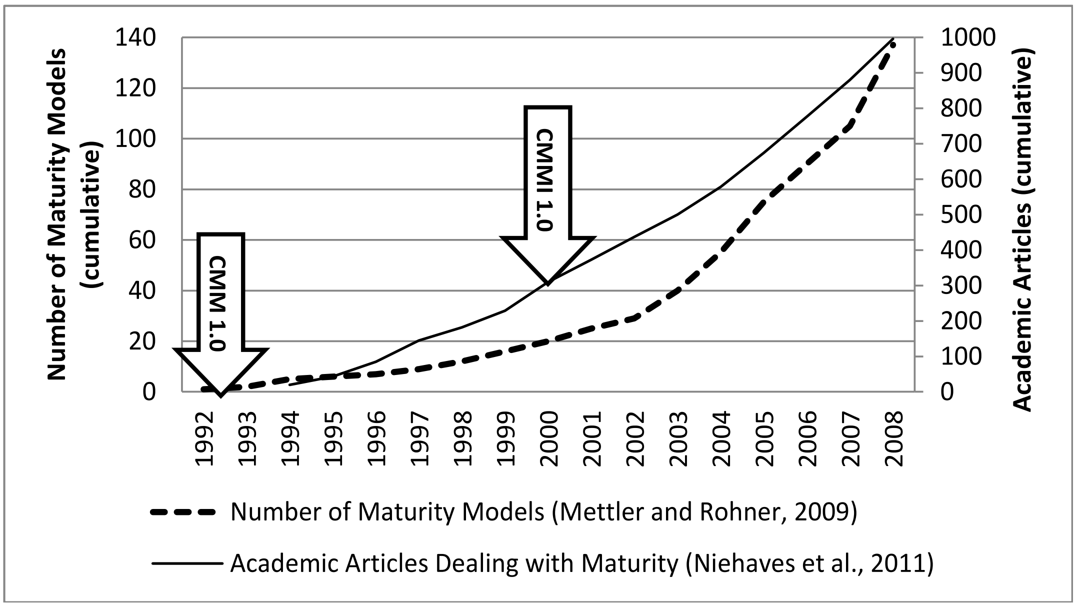

Figure 3.1: Trends in terms of new maturity models (Mettler and Rohner, 2009) and academic academic articles Niehaves *et al.* (2011)

Niehaves *et al.* (2011) searched for academic articles that deal with maturity within an organizational design context. Their results are included as the solid line on the secondary x-axis of Figure 3.1.

De Bruin *et al.* (2005) conducted a similar study, but did not limit their search to academic publications from a certain field. They also searched in the non-academic domain and counted over 105 maturity models developed by 2005.

3.2 Descriptive, Prescriptive and Comparative Models

Maturity models provide a way of measuring the status quo and facilitate an improvement process that best suits the enterprise, while remaining within the prescribed best practices parameters of the particular domain (Essman, 2009). Röglinger *et al.* (2012) confirm that "maturity models are used to assess "as-is" situations [descriptive], to guide improvement initiatives and to control progress [prescriptive]".

A descriptive maturity model is a diagnostic tool that is suitable for internal, external and longitudinal benchmarking (Maier *et al.*, 2012). It provides a snapshot of an organization's performance at a certain point and is normally driven internally (Pöppelbuß *et al.*, 2011). Prescriptive models provide guidelines on improvement measures and typically draw upon historical data from a significant number of applications (Niehaves *et al.*, 2011) to suggest specific and detailed courses of action

(Maier *et al.*, 2012). It enables the development of a road-map for improvement (De Bruin *et al.*, 2005). Prescriptive models typically draw upon historical data from a significant number of applications.

Some authors (De Bruin *et al.*, 2005; Pöppelbuß and Röglinger, 2011) add a third model type, namely *comparative* models. This kind of model allows for benchmarking across industries or regions and could also facilitate the comparison of similar practices or processes within and across organizations.

De Bruin *et al.* (2005) explain that each model type represents an evolutionary phase in the life cycle of a model. A deeper understanding of the "as-is" domain situation is firstly achieved by means of a descriptive model. After the model is applied a few times, it can then evolve and become prescriptive. Finally, for a model to be used comparatively, it must be applied in a wide range of organizations in order to obtain sufficient data to enable valid comparisons.

3.3 CMM-like Models, Maturity Grids and Likert-like Scales

Fraser *et al.* (2002) were the first to distinguish between CMM-like maturity models, maturity grids and hybrids. This categorization has appealed to others (Maier *et al.*, 2012; Mettler *et al.*, 2010; Pöppelbuß *et al.*, 2011) and is also of significance in this study. Table 3.1 was compiled by Fraser *et al.* (2002) to compare the maturity models available to them at that stage. Their categorization followed from this analysis.

3.3.1 CMM-like models

CMM-like models (Fraser *et al.*, 2002) are based on a more formal architecture. They specify a number of goals and key practices in reaching a predefined level of sophistication (Mettler *et al.*, 2010). Many CMM-like models follow a standard format, are internationally recognized and are also frequently used for certification purposes. To accommodate their complexity, CMM-like models need extensive support material and assessment training or benchmarking software (Mettler, 2012).

Within the context of health systems, the British National Health System (NHS) infrastructure maturity model (NIMM) (Savidas, 2009) is possibly the only maturity model that is sophisticated and comprehensive enough to be considered a comparative model. The MEDI SPICE model (Von Wangenheim *et al.*, 2012) has the potential to fit into this category, but it is yet to be completed.

Table 3.1: Comparison of maturity models (Fraser *et al.*, 2002)

Subject and reference	**Maturity levels** (Broens *et al.*, 2007)	**Approach**
Quality Management Maturity Grid (Crosby, 1979)	(1) uncertainty (2) awakening (3) enlightment (4) wisdom (5) certainty	grid, 6 issues, detailed description at each
R&D Effectiveness Audit (Szakoyi,1994)	(A) not recognized (B) initial efforts (C) skills (D) methods (E) responsibilities (F) continuous improvement	grid, 10 issues, detailed description at each
Technical Innovation Audit (Chiesa *et al.*, 1996)	(0) (1) (2) (3)	grid, 5 areas, 23 issues, detailed description at each level
Product & Cycle time Excellence McGrath *et al.* (1992)	(1) informal (2) functionally focussed project management (3) cross-functional project management (4) enterprise wide integration of project development	grid, 10 issues, detailed description at each
Design Maturity Model Fraser *et al.* (2001)	Operational Product	Sustained Operation
Collaboration maturity model (Fraser and Gregory,2002)	(1) none (2) partial (3) formal (4) culturally embedded	grid, 7 issues, detailed descriptions and captions
Supplier relationships (Macbeth and Ferguson, 1994)	(1) adversarial (2) traditional (3) partnership	grid/likert-hybrid, 9 issues, brief description at 3 levels plus 7 point scale
ISO9004 (ISO 9004:2000)	(1) no formal approach (2) reactive approach (3) stable formal system approach (4) continual improvement emphasised (5) best in class performing	global levels defined, 5 questions, 11 issues
Project Management Maturity (Dooley *et al.*, 2001)	(1) (2) (3) (4) (5)	Likert style questionnaire, 15 areas, 85 issues, no description of performance
Software CMM - Staged maturity levels (Paulk *et al.*, 1993)	(1) initial (2) repeatable (3) defined (4) managed (5) optimizing	CMM style
Agile maturity model (change proficiency) (Dove, 1999)	(1) accidental (2) repeatable (3) defined (4) managed (5)mastered	CMM style
Usability maturity (human factors) (Earthy, 1998)	(X) unrecognised (A) recognised (B) considered (C) implemented (D) integrated (E) institutionalised	CMM style
CMMI continuous: capability levels (Shrum, 2000)	(0) not performed (1) performed (2) managed (3) defined (4) quantitatively managed (5) optimizing	CMM style
Capability assessment framework (Wognum and Faber, 1999)	(2) repeatable (3) defined (4) managed (5) optimizing	CMM style

3.3.2 Maturity grid

According to Maier *et al.* (2012) maturity grids are generic tools that define the characteristics of high performance processes, irrespective of the company or enterprise. Fraser *et al.* (2002) explains that "the principal idea of the maturity grid is that it describes in a few phrases, the typical behaviour exhibited by [an organization] at a number of levels of maturity, for each of the several aspects of the area under study."

A typical maturity grid allows the visualization of maturity levels, which is not necessarily the case for CMM-like models. Maturity grids aim to illustrate a number of levels of maturity in a simple, textual manner (Mettler *et al.*, 2010) and are typically descriptive frameworks, used for self-assessment purposes. Since the purpose of a maturity grid is not that of certification, it tends to be a simpler diagnostic and improvement tool. Companies often follow a number of parallel approaches, but maturity grid assessment can be used independently, as a subset of a broader improvement initiative (Maier *et al.*, 2012).

3.3.3 Hybrids and Likert-like scales

Hybrids and Likert-like questionnaires are comparable with maturity grids. However, the focus is more on scoring specific statements of good practice and not on describing the overall levels of maturity (Mettler *et al.*, 2010).

Technology-readiness, system readiness and organizational-readiness instruments are typical examples of this sort of maturity assessment (Maier *et al.*, 2012). Many readiness instruments have already been developed and are in use within the context of telemedicine and eHealth (Jennett *et al.*, 2005; Legare *et al.*, 2010; Khoja *et al.*, 2007). These instruments are elaborated upon in Chapter 4. The scoring systems of the Khoja-Durrani-Scott (KDS) evaluation framework (Khoja *et al.*, 2007), as well as the model for assessment of telemedicine applications (MAST) (Kidholm *et al.*, 2012), are also based on Likert-like scales.

3.4 Maturity

The glossary of the Systems Engineering Capability Maturity Model (Bate *et al.*, 1995) provides a definition for *capability*, *capability level*, *capability maturity model maturity level* as well as *maturity model*. However, it does not provide a definition for *maturity*. Likewise, most publications on this topic provide a definition for a *maturity model* (Fraser *et al.*, 2002; De Bruin *et al.*, 2005; Essman, 2009; Mettler and Rohner, 2009; Kohlegger *et al.*, 2009; Maier *et al.*, 2012), but very few (none of the authors referenced here) elaborate on the concept of *maturity*.

A possible reason for this may be a general consensus on the meaning of the concept *maturity* from a psychological point of view. The analogy drawn from the the business world is clear and it thus may thus seem unnecessary to contest the definition. In this section, the parallels between organizational maturity, as it applies to this thesis, and human maturity are considered.

> Maturity is a psychological term used to indicate how a person responds to the circumstances or environment in an appropriate manner. This response is generally learned rather than instinctive, and is not determined by one's age ... knowing when to act appropriately according to the situation and the culture of the society one lives in (Weschler, 1950).

This definition of psychological maturity within the context of human development, has been cited by many scholars and provides a basis for the comparison between psychological maturity and organizational maturity.

3.4.1 Organizational learning

> Maturity is a psychological term used to indicate how a person responds to the circumstances or environment in an appropriate manner. This response **is generally learned rather than instinctive**, and is not determined by one's age. (Weschler, 1950).

Maturity is not just about a current state: it also implies the notion of moving from some initial state to a more advanced state. According to Fraser *et al.* (2002), this suggests that the subject may pass through a number of intermediary states en route to maturity. In the development of capability-maturity models, an explicit assumption is that a perfected end-state exists, whether it unfolds from within or is designed from the outside (Fraser *et al.*, 2002). A maturity model is not only used to assess the current state, but also facilitates the process of moving towards the perfected end-state.

3.4.2 Organizational entity under consideration

> Maturity is a psychological term used to indicate how **a person** responds to the circumstances or environment in an appropriate manner. This response is generally learned rather than instinctive, and is not determined by one's age ... knowing when to act appropriately according to the situation and the culture of the society one lives in (Weschler, 1950).

Here the maturity of a **person** is considered within a psychological context. Mettler (2011) and Niehaves *et al.* (2011) identified three groups of **organizational entities** that are typically measured through maturity models, within an organizational context:

Process maturity refers to the extent to which a specific process is explicitly defined, managed, measured, controlled and effective. It is focussed on activities and work practices. The underlying goal of process-orientated maturity is almost always efficiency.

Object or technology maturity refers to the extent to which a particular object or technology reaches a predefined level of sophistication.

People or culture maturity relates to the extent to which the workforce can create knowledge and enhance proficiency.

3.4.3 Domains and dimensions

> Maturity is a psychological term used to indicate how a person responds to the circumstances or environment in an appropriate manner. This response is generally learned rather than instinctive, and is not determined by one's age ... knowing when to act appropriately **according to the situation and the culture of the society one lives in** (Weschler, 1950).

Like psychological maturity, which depends on the situation and culture, the organizational context affects the way in which organizational maturity is viewed. Most (possibly all) maturity models include at least one of the following design components: domains or dimensions. These components are used to provide the context for the measurement of maturity. The organizational entity exhibits different levels of maturity depending on the domain and depth of dimension under consideration.

As with the concept of *maturity*, many authors use the terms *domain* or *dimension* without explaining their understanding of the termininology. This may be because they assume a universal understanding of these terms, at least with respect to their target audience. These terminologies are not used consistently and are often used interchangeably in the same publication. It was not possible to find universally agreed upon definitions for these concepts. The definitions that are adopted for the purposes of this study are presented here:

3.4.3.1 Domain

Some authors (Haris, 2010; Kidholm *et al.*, 2012; Procter *et al.*, 1995) considers domains as components of a maturity model while for others an entire model fits within a specific domain (Pöppelbuß *et al.*, 2011; De Bruin *et al.*, 2005; Van de Wetering, 2009).

The definitions of Kidholm *et al.* (2012) and Merriam Webster (2013) are combined to come up with a definition for *domain* for the purposes of this study: A domain is a sphere of activity, concern, or function (Merriam Webster, 2013) and represents an angle from which to view the use, consequences and implications (Kidholm *et al.*, 2012) of the entity under consideration.

3.4.3.2 Dimension

The generic definition for this concept, as stipulated in the *Cambridge International Dictionary of English* are adopted here, namely "the measurement (of something) in a particular direction" (Procter *et al.*, 1995).

3.4.4 Capability and maturity levels

> Maturity is a psychological term used to indicate how a person responds to the circumstances or environment in an appropriate manner. This response is generally learned rather than instinctive, and is not determined by one's age ... knowing when **to act appropriately** according to the situation and the culture of the society one lives in (Weschler, 1950).

A particular response can be expected from a person with a certain level of maturity. The way in which a person responds or acts is indicative of his level of maturity. Similarly, the maturity of a process is usually shown by its so-called capability. The maturity level refers to "the **degree** of process improvement", while capability indicates the "**achievement** of process [or object] improvement" (Bate *et al.*, 1995).

Crosby (1979) inspired the notion of progressing through stages towards maturity. He did not, however, formalize the concept of measuring organizational capabilities. The concept of *capability* was introduced through the family of capability maturity models (CMMs). The significant influence of these models on the development of other models was indicated in Section 3.1.1. It is common for a maturity model to incorporate the notion of capability by linking the *capability* of an organization, or organizational unit, with the maturity level.

Statistical process control (SPC) - as part of Total Quality Management (TQM) - originates from the manufacturing environment as method to continuously monitor all manufacturing processes to ensure that they operate according to their capability (Croarkin and Tobias, 2012). Cooke-Davies (2004) explains that the family of capability maturity models draws on the concept that every process has a natural capability, which can be measured and controlled. This is an underlying principle in the formulation of the maturity levels for the CMMs (Bate *et al.*, 1995).

A process is matured to a stage of standard operation (level 3). Further maturity levels indicate process control and measurement (level 4) and improvement (level 5). Scott (2010) too recognizes in his *Pragmagtic Evaluation of Telemedicine Interventions* (Section 4.5.2) that continuous process improvement follows the measurement of the value of the process.

In the CMMI, maturity levels are defined as follows:

1. **Initial (chaotic, ad hoc):** The starting point for use of a new or undocumented process.
2. **Repeatable:** The process is sufficiently documented so that repeating the same steps may be attempted.
3. **Defined:** The process is defined/confirmed as a standard business process.

4. **Quantitatively Managed:** The process is quantitatively managed in accordance with agreed-upon metrics.
5. **Optimizing:** Process management includes deliberate process optimization/ improvement.

Capability levels are often expressed as a set of improvement measures, criteria (De Bruin *et al.*, 2005; Mettler, 2011), common features, key practices, goals within a process area (Paulk *et al.*, 1993; Bate *et al.*, 1995), or capability statements. Savidas (2009) explains that for the NHS infrastructure maturity model (NIMM) "generic capability statements are the most useful way of describing 'what life is like' ... at each of the five levels." Pöppelbuß and Röglinger (2011) describe *capabilities* as repeatable patterns of action.

Maturity levels are presented as different discrete stages, while improvement measures, common features, key practices goals or capability statements are typically positioned along a continuous scale of capability levels (Bate *et al.*, 1995). This continuous scale also implies that a higher capability level implicitly includes the attributes of the lower levels.

Within the scope of this study, capability statements are used as mechanism to describe the capability of a process. A capability statement is defined as generic statement that describes a characteristic of a process as it applies to a specific maturity level.

3.4.5 Capability areas and process areas

Pöppelbuß and Röglinger (2011) found from the work of De Bruin *et al.* (2005), Hammer (2007) and Weber *et al.* (2008), that a combination of different dimensions, different maturity levels as well as different levels of granularity are represented through concepts such as *capability areas*, *factors*, *process areas*, *enablers*, or *enterprise capabilities*. Jokela *et al.* (2006) also recognizes *capability areas*, *process areas* as well as *foci of assessment* as recurring components of many maturity models.

The ways in which these concepts are defined and used varies depending on the specific maturity model under consideration. Two of these concepts are used within the scope of this study and are defined as follows:

Process Area: A cluster of related activities, associated with a specific maturity level that, when performed together, achieve a set of goals considered important (Bate *et al.*, 1995).

Capability Area: A cluster of related activities, associated with a specific combination of dimensions and spanning all maturity levels.

3.4.6 Organizational life cycle

> Maturity is a psychological term used to indicate how a person responds to the circumstances or environment in an appropriate manner. This response is generally learned rather than instinctive, and is **not determined by one's age** ... knowing when to act appropriately according to the situation and the culture of the society one lives in (Weschler, 1950).

Maturity is a human characteristic that is attributed to organizations. Similarly, the human life cycle is often used as a metaphor for an organizational life cycle: birth-growth-maturity-decline-death (Whetten, 1987). So too within the context of telemedicine, some of the frameworks discussed in the next chapter recognize that telemedicine goes through different life cycle stages (refer to Table 3.2). These phases are often deliberately considered when a telemedicine service is developed and deployed, particularly in the case of top-down initiatives.

Table 3.2: Typical telemedicine/ ehealth life cycle stages

Systematic approach to the evaluation of ehealth interventions (Scott, 2010)	**Layered telemedicine implementation model** (Broens *et al.*, 2007)	**Stages of the ehealth life cycle** (Khoja *et al.*, 2013*a*)
Pre-ehealth		
Development	Prototype	Development
Implementation	Small-scale Pilot	Implementation
Integration	Large-scale Pilot	Integration
Sustained Operation	Operational Product	Sustained Operation

There are, however, some telemedicine services that have been initiated by individuals or small groups of health care practitioners, without consideration of the life cycle stages. Although such practitioners have not given much thought to the various stages of the service, they have gone through phases of experimentation and implementation, before operationalizing the service in a sustainable way. In any case maturity models can be instrumental in facilitating the organizational growth process in reaching maturity. Either way, it seems certain that maturity models can be instrumental in facilitating the organizational growth process and help these services reach maturity. They can then also continue to be of use in maintaining the maturity levels and in so doing, prevent organizational decline and the ultimate demise of a telemedicine service.

As with a human being, who's maturity is not necessarily determined by his physical age, the organizational life cycle phase does not necessarily determine the level of organizational maturity. Although one can expect some correlation, the life cycle phase does not automatically equate to maturity level. For example, a telemedicine service, undergoing technological development or prototype phase, may exhibit high levels of maturity in terms of methods, while another service in a large-scale pilot phase may have low levels of maturity in terms of financial processes.

For a service to function optimally, a holistic view on maturity is needed. All determinants for the success of a service must be addressed simultaneously and synergistically, irrespective of the life cycle stage.

3.4.7 Maturity of telemedicine services

Most publications on organizational maturity circumscribe, rather than define, the concept of *maturity*. Hence, in this section, a definition for maturity was taken from the from the field of Psychology to investigate the issues relating to organizational maturity. To conclude this section a new definition is presented for the purposes of this study:

The maturity of a telemedicine service indicates the capability of the service, within different domains and dimensions, expressed according to a certain level of maturity.

3.5 The Science of Maturity Models

> The world of everyday life is the ordinary and physical reality in which we exist, the ordinary problems we have to solve and the ordinary lessons we learn. The *world of science and scientific research* takes issues from the world of everyday life and makes these into objects of systematic and rigorous enquiry (Mouton, 2001).

Section 3.1 described the origin and evolution of maturity models. It was found that the development of maturity models was primarily driven by industry needs. More recently (about a decade ago) maturity models became a topic of interest to academic scholars. Under academic scrutiny, maturity models which were developed for use in the world of everyday life, are turned into objects of systematic and rigorous enquiry. In this section the focus is on a scientific approach towards the development of a maturity model.

3.5.1 Iterative design approach

Solli-Saether and Gottschalk (2010) suggest a developmental approach, similar to the approach seen in Figure 3.2 for a stages-of-growth model, such as maturity models. Their procedure takes into account two issues that are mentioned and/or practiced by others: first, the iterative nature of the maturity model development process (De Bruin *et al.*, 2005; Strehle and Shabde, 2006; Von Wangenheim *et al.*, 2010; Essman, 2009; Niehaves *et al.*, 2011; Mettler, 2011; Röglinger *et al.*, 2012)

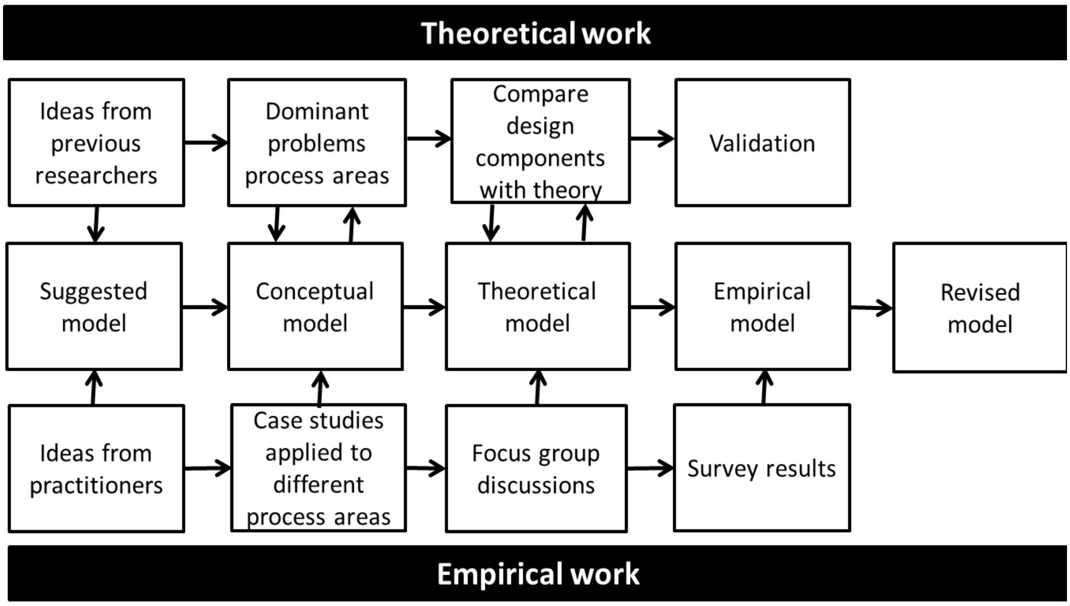

Figure 3.2: Procedure for the development of a stages-of-growth model (Solli-Saether and Gottschalk, 2010)

and secondly, the need to combine theoretical and empirical research (De Bruin *et al.*, 2005; Thomas, 2007; Solli-Saether and Gottschalk, 2010).

3.5.2 Top-down approach vs bottom-up approach

When developing a maturity model, either a bottom-up or a top-down approach can be followed. In a bottom-up approach capabilities/ factors/ foci/ enablers are defined first and then, based on these definitions, maturity is defined to reflect these, and the rest of the maturity model is constructed. With a top-down approach (De Bruin *et al.*, 2005), the maturity and other constructs are defined first, followed by the measures or capability statements (Mettler, 2011).

De Bruin *et al.* (2005) explains that "a top-down approach works well if the domain is relatively naïve and there is little evidence of what is thought to represent maturity. The emphasis in this instance is first on what represents maturity, and second how can this be measured." For the development of the TMSMM a top-down approach is followed. The conceptual model (Chapter 5) was developed first, followed by a definition of the capability statements are defined within the framework, provided by the conceptual maturity model (Chapter 6).

3.6 Design Requirements

As part of their contribution to the scientific rigour of the development of maturity models, Pöppelbuß and Röglinger (2011) conducted a systematic review of the development of a significant number of maturity models. From this, they defined a number of design considerations. These considerations, as they apply to descriptive maturity models, are grouped into two categories for the purposes of this discussion.

Design considerations in terms of methodology

These considerations apply to the model development methodology.

- Differentiation from related maturity models and frameworks
- Underpinning foundations with respect to evolution and change
- Definition of central constructs
- Design process and extent of empirical validation

Considerations related to design requirements

These considerations provide structure for the rest of this section, in which the design requirements for the TMSMM are defined. These design requirements are also revisited in Chapter 8 to verify that the TMSMM does indeed satisfy all of these.

- Application domain
- Purpose
- Target group
- Class of entities under investigation
- Domains, dimensions, maturity levels and maturation paths
- Available level of granularity of maturation

3.6.1 Application domain

The application domain of the TMSMM concerns telemedicine services. For the purposes of this study, telemedicine is defined as the delivery of healthcare (*medicine*) where distance (*tele*) is an issue. The first design requirement encapsulates this domain.

Design Requirement 1: The TMSMM can describe any healthcare service that is delivered over a distance (telemedicine service).

3.6.2 Purpose

The difference between descriptive, prescriptive and comparative maturity models is described in Section 3.2. De Bruin *et al.* (2005) explain that each model type represents an evolutionary phase in the model's life cycle. A deeper understanding of the "as-is" domain situation is firstly achieved by means of a descriptive model. After the model is applied a few times, it can then be further developed to become prescriptive. The TMSMM is in the first place a descriptive model, which lead to the second design requirement:

Design Requirement 2: The TMSMM enables the assessment of the maturity of the service.

The TMSMM is also a prescriptive maturity model which guides and educates stakeholders towards the initialization, standardization and optimization of these services.

Design Requirement 3: Based on each service assessment, further steps towards the achievement of the target maturity state are indicated.

3.6.3 Target group

De Bruin *et al.* (2005) recommend that decisions concerning the granularity (level of detail) of the maturity model are based on the intended target audience. A maturity model has two target groups: those who would use the maturity model to describe and assess the processes (internal stakeholders) and those who are interested in the reported results (internal and external stakeholders). A high level of abstraction is suitable for interaction with external stakeholders, on a strategic decision making level, while a lower level of abstraction helps internal stakeholders manage maturity within complex domains. It also aids in choosing improvement measures.

3.6.3.1 Internal stakeholders

In terms of internal stakeholders, the TMSMM is targeted at individuals involved in the development and/or operation of telemedicine services. These stakeholders could be involved in any aspect of the telemedicine process, ranging from patients, healthcare fieldworkers, or ICT technicians, to nurses, health system managers and specialists. Many of these stakeholders are non-specialists when it comes to telemedicine. The TMSMM must therefore be designed to be useful to non-specialists from multiple disciplines. Further maturity models, like any reference model (OASIS, 2013) "may be used as basis for eduction and explaining standards to a non-specialist".

Depending on the complexity of the telemedicine service, the TMSMM can be used by an individual or a group of people. The requirement of the model for the assessment of telemedicine (MAST) (Kidholm *et al.*, 2012) to enable multidisciplinary assessment, is also relevant to the TMSMM. Multidisciplinary assessment teams can also help to overcome the bias of single-informants, to build cross-functional consensus and to raise buy-in on initiatives (Fraser *et al.*, 2002; Burger *et al.*, unknown publication date).

Design Requirement 4: The TMSMM can be used as basis for education and explaining standards.

Design Requirement 5: The maturity assessment methodology can be followed easily and intuitively.

Design Requirement 6: Role players from multiple disciplines can use the TMSMM to describe and assess the telemedicine service at the level on which they are engaged.

3.6.3.2 External stakeholders

External stakeholders are not directly involved in the telemedicine service or the assessment of the maturity of the service. They are interested in viewing the assessments on a higher level of abstraction. For example, in the recent eHealth Strategy of the South African NDoH (Government, 2012) reference was made to "widely differing levels of eHealth maturity across and within provinces". Decision makers at governmental level or within certain provinces, would therefore be interested in an analysis of the maturity of a cohort of services within a certain health system.

Other examples of external stakeholders that may be interested to understand the maturity of certain cohorts of services, are identified by Khoja *et al.* (2007, 2013*a*). Their framework provides different views for different stakeholders, for example managers or service providers.

Design Requirement 7: Results from a cohort of individual service descriptions and assessments can be aggregated along dimensions culminating in an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic level decision-makers.

> There is value for any single entity (healthcare organisation, sub-national region, country) to identify and adopt a single model or framework. Doing so permits the evidence gathered to be more meaningfully compared, and individual evaluations then collectively and rapidly accumulate the broad evidence-base needed to demonstrate the value of ehealth interventions (Scott, 2010).

3.6.4 Class of entities under investigation

The way in which the TMSMM measures maturity should focus on the telemedicine service, rather than the maturity or the complexity of related elements. For example, state-of-the-art technology does not necessarily result in a mature telemedicine service. Likewise, a service can be mature, even though it is delivered using elementary technology. Savidas (2009) states, for example, that the NHS infrastructure maturity model (NIMM) must not be technology-independent and Kidholm *et al.* (2012) define the principle of unbias for the model for the assessment of telemedicine applications (MAST).

Design Requirement 8: The TMSMM is not directly tied to any standards, technologies or concrete implementation details.

3.6.5 Domains, dimensions, maturation paths and capability statements

As a reference model, the capability statements of the TMSMM need to be a complete set (OASIS, 2013), which implies the following design requirements:

Design Requirement 9: The capability statements are mutually exclusive.

Design Requirement 10: The capability statements are collectively exhaustive.

Maturity models describe typical patterns in the development of organizational capabilities and usually depict a sequence of stages. Together, these stages form an anticipated, desired or logical path from an initial to a target maturity state (De Bruin *et al.*, 2005; Solli-Saether and Gottschalk, 2010; Pöppelbuß *et al.*, 2011).The final two design requirements are defined accordingly:

Design Requirement 11: Descriptions of capability statements clearly relate to and discriminate between maturity levels.

Design Requirement 12: The capability statements and maturity levels accumulate. Each level and statement also includes the preceding lower level statements.

3.7 Conclusion

This chapter addressed two of the research objectives:

Research Objective 2: Understand the science and design considerations of maturity models and define concepts, approaches and paradigms relevant to this study.

Research Objective 3: Define design requirements for a telemedicine maturity model.

The development of maturity models was inspired by theories and frameworks from the world of science, such as Maslow's Hierarchy of Human Needs, Kuznet's Theory of Economic Growth and Nolan's stages-of-growth model. Since the early 1980's, maturity models have become popular in the world of everyday life as instruments to manage, standardize, measure and optimize processes in complex systems and projects.

Recently, researchers such as Fraser *et al.* (2002); De Bruin *et al.* (2005); Jokela *et al.* (2006); Niehaves *et al.* (2011); Mettler (2011); Pöppelbuß *et al.* (2011); Pöppelbuß and Röglinger (2011) and Maier *et al.* (2012) have started to consider the development and application of these models in the world of everyday life. Their ultimate purpose, however, is to contribute truthful, valid and reliable descriptions, models and theories (Mouton, 2001) to the world of science.

Concepts, approaches and paradigms relevant to this study were taken from the work of these authors and presented in this chapter. In the event of insufficient consensus among researchers, definitions were formulated for the purposes of this study and design requirements for a maturity model for telemedicine services were defined accordingly.

The next chapter 'marries' the two research domains that have been individually considered in Chapter 2 (the telemedicine landscape) and this chapter (maturity models). In Chapter 4 telemedicine frameworks are presented and mapped against the design requirements in the quest for a framework that satisfies all these requirements.

Chapter 4

Telemedicine Frameworks

The previous chapters considered the telemedicine landscape as well as the science of maturity models in order to define a set of design requirements that such a model should adhere to. The next objective is to search for a framework that satisfies all these requirements. This is done according to the research roadmap of Figure 4.1.

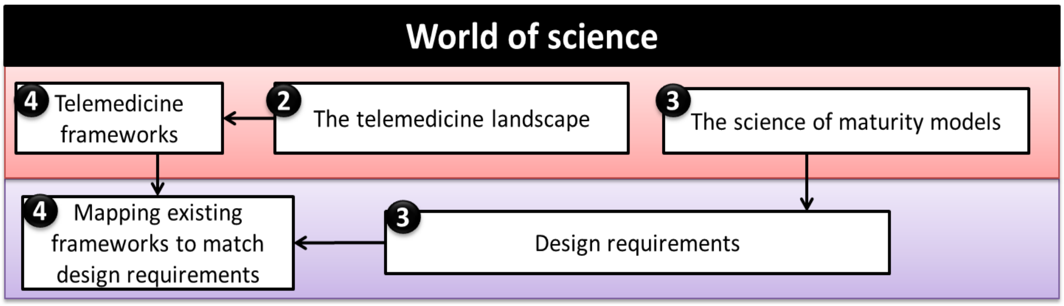

Figure 4.1: Requirements mapping

The following three questions are asked:

Research Question 4.1: What telemedicine reference models, frameworks or guidelines exist?

Research Question 4.2: Which design requirements are satisfied by each of the respective frameworks?

Research Question 4.3: Do any of these frameworks satisfy all the design requirements?

4.1 Framework Categories

Principles, attributes, lessons, elements, influences, frameworks, critical steps, instruments and *models*: these are all terms used to describe the concepts presented in this chapter. For the sake of uniformity, in this chapter, all these are collectively referred to as *frameworks*, hence the title of this chapter. For discussion purposes, similar frameworks are grouped together:

The diffusion of innovation: Tanriverdi and Iacono (1998, 1999) and Grigsby *et al.* (2002) consider the relevance of theories for the diffusion of innovation to the implementation of telemedicine services. These two frameworks are discussed first in Section 4.1, because many of the frameworks that follow contain aspects of Tanriverdi and Iacono (1998).

eReadiness refers to the degree to which a community is prepared to participate and succeed in an ICT-driven service. It concerns the beginning of the implementation life cycle. Section 4.3 considers a few eReadiness frameworks as well as the unified theory of acceptance and use of technology (UTAUT), as it is applied to telemedicine and ehealth.

Retrospective guidelines contain issues that should be addressed during the implementation or scaling up of a telemedicine service. These guidelines, which appear in Section 4.4, were typically compiled retrospectively from the experience of implementing a number of telemedicine services.

Staged frameworks recognize the fact that different dynamics are applicable to different stages. Two types of staged frameworks are included in this chapter: First, those that consider the dynamics of different *life cycle stages* of the telemedicine service (Section 4.5) and, second, frameworks related to telemedicine that facilitate different maturity and capability levels (Section 4.6).

Other frameworks for the evaluation of telemedicine services: This section considers two frameworks which were specifically developed for the evaluation of telemedicine services, but which do not fit within any of the previous sections. These two models are the so-called comprehensive model for evaluating telemedicine (Hicks *et al.*, 2004) and the model for the assessment of telemedicine (MAST) (Kidholm *et al.*, 2012).

As each of these frameworks are presented, the extent to which they satisfy the TMSMM design requirements is considered. These conclusions culminate in Section 4.8 in order to determine if any of these frameworks satisfy all the design requirements.

4.2 Frameworks Related to the Diffusion of Innovation

For the past few decades, researchers have been intrigued by innovation and the factors that impact their diffusion. This interest has intensified as technology and technological innovations develop and the complexity of enterprises increases. With the Barriers to the diffusion of telemedicine publications (Tanriverdi and Iacono, 1998, 1999) and the Influences on the diffusion of telemedicine (Grigsby *et al.*, 2002), some of these concepts have been brought into the telemedicine research domain.

Rogers' (1995) categories of innovation adoption, namely innovators, early adopters, early majority, late minority and laggards can be recognized in the diffusion of telemedicine innovation. During the first few decades after the term *telemedicine* was used for the first time (1970), mainly the pi0oneering initiatives by innovators followed (ETHAL, 2008; Edwards, 2011). Then, from about 1995, motivated by significant ICT developments (Grigsby *et al.*, 2002; Bashshur *et al.*, 2000), it was not only the pioneers and innovators, but also the early adopters who used telemedicine applications to improve their daily work in healthcare. Today telemedicine is becoming a key issue in the implementation of healthcare services and is of interest to the early majority.

4.2.1 Barriers to the diffusion of telemedicine

Tanriverdi and Iacono (1999) were the first to recognize that insights concerning the diffusion of innovation can be applied to the implementation of telemedicine services. They based their research on the work of Attewell (1992) concerning Technology diffusion and organizational learning and defined four so-called innovation barriers. They went on to translate these into barriers for the diffusion of telemedicine: these barriers and some of their observations with respect to telemedicine are listed below:

Technical barrier: It is imperative that the appropriate technology is available as well as knowledge about it.

Behavioural barrier: This barrier involves change management, especially with respect to resistance to change and the power and politics surrounding telemedicine. Tanriverdi and Iacono (1999) emphasized the importance of so-called *proponents of telemedicine* in accomplishing this change.

Economical barrier: Two major concerns of Tanriverdi and Iacono (1999) were to reimburse healthcare workers for telemedicine consultations and to open up new patient markets.

Organizational barrier: Tanriverdi and Iacono (1999) found the integration of telemedicine services (and the institutional support necessary to execute these services), into organizational structures to be of critical importance.

4.2.2 Influences on the diffusion of telemedicine

Scott (1990) brought Rogers' diffusion of innovation theory into the healthcare domain by applying it to medical care organizations. Grigsby *et al.* (2002) narrowed the focus to telemedicine services and compiled a list of factors that influence the adoption of innovative technologies, based on the work by (Scott, 1990). These factors are listed in the left-hand column of Table 4.1. Grigsby *et al.* (2002) added, what they considered at that stage, to be of relevance to telemedicine.

4.2.3 Design requirements satisfied by these frameworks?

The fourth objective of this study is to search for a framework that satisfies all the design requirements. The extent to which the two frameworks from this section, satisfy all the design requirements is discussed below. The results of this discussion are summarized in Table 4.5 at the end of this chapter.

The two frameworks described in this section, satisfy some of the design requirements: both of these frameworks apply to telemedicine services (DR 1 satisfied) and both can be used as a basis for education and explaining standards (DR 4 satisfied), although they are not directly tied to any standards, technologies or concrete implementation details (DR 8 satisfied). In addition, these frameworks can be used by non-specialists (DR 6 satisfied) as well as external stakeholders, researchers and strategic level decision-makers (DR 7 satisfied).

However, there are a few design requirements they do not satisfy: neither of these frameworks provides a means of assessing a telemedicine service and prescribing actions towards optimization, nor do they provide an interface to accomplish this (DRs 2,3 and 5 not satisfied). Furthermore, Tanriverdi and Iacono (1998, 1999) do not provide any statements that give an indication of capability (DRs 9,10,11 and 12 not satisfied). It may be argued that the list of Influences on the Diffusion of Telemedicine by Grigsby *et al.* (2002) constitutes capability statements, which are mutually exclusive (DR 9), but they are not collectively exhaustive (DRs 10 not satisfied). Instead, they are aligned with maturity levels and are not in sequence (DRs 11 and 12 not satisfied).

Table 4.1: Influences on the diffusion of telemedicine (Grigsby *et al.*, 2002)

Factor	**Relevance to Telemedicine**
Authoritarian decision-making	Adoption fastest when the decision to adopt is made by an individual with authority to enforce the decision
Capable of pilot test	Depending on technology and application, there may be sufficient opportunity for pilot testing
Communication channels	Information dissemination most effective if done by peers with similar interests and concerns
Compatibility with status quo	Significant systemic changes may be required in the way care is provided
Complexity of skills required	Reasonable learning curve, but requires acquisition of new habits associated with providing care
Consistency with social norms	Greater likelihood of adoption when an innovation is close to the professional/organizational mainstream
Cost of the technology	Relative cost to institution varies by site; absolute costs decline but are excessive for small/rural facilities
Effect on quality of services	Quality probably comparable to in-person care; possible improvement associated with increased access
Improvement in efficiency	Little increase in efficiency for many applications, especially using video-conferencing, because of inconvenience
Organizational change required	Some degree of change may be required, but not necessarily disruptive to ordinary processes of care
Organizational/social structure	Diffusion facilitated by hierarchical, authoritarian systems, and hampered by loosely organized systems
Return on investment	Revenue is minimal, but this varies by application, size of facility, and geographic location
Risk or uncertainty	Payment for services is questionable, as is the issue of whether providers will use the service
Role of opinion leaders	Mainstream, charismatic individuals are likely to influence their peers to adopt new technology
Significance of research data	Important for early adopters, but less important than interpersonal channels involving professional peers
Social approval	Moderately high appeal to general public and news media, but many providers remain skeptical

4.3 eReadiness Frameworks

Theories on the adoption and diffusion of innovation form the basis for theories on readiness as well as Lewin's three phase model (Jennett *et al.*, 2005). eHealth and telemedicine readiness is defined as the degree to which a community is prepared to participate and support an ehealth or telemedicine service. This is normally measured before the implementation of the service (Khoja *et al.*, 2007) and considers the capacity for making changes as well as the perceived need to change. Jennett *et al.* (2005) specifically refer to ehealth readiness when arguing that time, money and energy can be saved if the status quo of an ehealth/telemedicine system context is determined before implementation.

A few readiness instruments have already been developed and are in use within the context of telemedicine and ehealth. Legare *et al.* (2010) identified six different assessment tools that use Likert scale questionnaires to measure e-readiness within a certain health care context. The first of these tools was developed in 1996: The Organizational information technology/systems innovation readiness scale supports the evaluation, diagnosis and treatment selection for different steps in patient care, in the context of telehealth.

The second, third and fourth tools mentioned by Legare *et al.* (2010) were built upon each other and are focussed on home-based telehealth applications. Khoja *et al.* (2007) developed the eHealth readiness assessment toolset for healthcare institutions in developing countries. Jennett *et al.* (2005) developed the Telehealth Readiness Assessment Tool that focusses on ehealth applications in rural settings.

4.3.1 eHealth readiness assessment tools for healthcare institutions in developing countries

This toolset by Khoja *et al.* (2007) is singled out for three reasons. First, it forms the basis of a recent evaluation framework by the same group of researchers (Khoja *et al.*, 2013*a*), which is considered in the next section. Secondly, this toolset has had the best reception from the academic community, if measured by the rate at which it is cited by others. A few authors have used this as a reference in the development of other telemedicine and ehealth assessment frameworks (Chattopadhyay *et al.*, 2008; Tamburis *et al.*, 2012; Leon *et al.*, 2012) and two publications on ehealth readiness have specifically referred to this toolset.

Chipps and Mars (2012) assessed the preparedness of health districts and designated hospitals in the KwaZulu-Natal (KZN) province for proposed telepsychiatry services. They concluded that for telepsychiatry to succeed in KwaZulu-Natal, a change management awareness is needed. However, it is not clear if and how the ehealth readiness assessment toolset will assist with this.

Durrani *et al.* (2012) used this toolset to measure the ehealth readiness of two separate ehealth programmes, one in Kabul and the other in Bamyan. The ehealth readiness assessment toolset was found to be useful, firstly, in comparing the ehealth readiness of these two programmes, and secondly in "broadening the vision of the institutions as a whole".

The third reason why these assessment tools have been singled out, is because they were components of the workshops that provided empirical input for the development of the TMSMM. These workshops are elaborated upon in Section 5.1.2.1.

The set of eHealth readiness assessment tools for healthcare institutions in developing countries (Khoja *et al.*, 2007) covers five categories. Each category contains a number of statements with which a respondent is asked to agree/disagree with, according to a 5-point Likert scale. Each of these statements addresses a single determinant of access to ehealth. The way in which each statement is expressed, together with the Likert scale, provides a means of quantifying the perceived ehealth readiness.

1. **Core Readiness** (21 statements) deals with aspects of planning and integration.
2. **Technological Readiness** (10 statements) considers availability, reliability, affordability and ICT, and related infrastructure.
3. **Learning Readiness** (6 statements) addresses issues related to the programs and resources available for the provision of training in the use of the technology.
4. **Societal Readiness** (11 statements) considers the interaction between the institution and other institutions in the region and beyond. Socio-cultural factors are also included.
5. **Policy Readiness** (12 statements) deals with policies, at government and institutional levels, which are in place to address common issues such as licensing, liability and reimbursement.

Khoja *et al.* (2007) grouped these sets of statements into two so-called toolsets. The first toolset is targeted at managers and includes Core readiness, Technological readiness, Societal readiness and Policy readiness, excluding Learning readiness. The second toolset, which is targeted at healthcare providers, includes Core readiness, Learning readiness, Societal readiness and Policy readiness, but not Technological readiness.

Table 4.2 is compiled to show the relationship between the work of Tanriverdi and Iacono (1998) and the work of Khoja *et al.* (2007). The barriers to the successful implementation of telemedicine (Tanriverdi and Iacono, 1998) are indicated in the first column. The toolsets of Khoja *et al.* (2007) are indicated in the second (micro level) and third (macro level) columns. Khoja *et al.* (2007) did not differentiate between these two levels. This differentiation is made for purposes of this study.

Table 4.2: Relationship between Tanriverdi and Iacono (1998) and Khoja *et al.* (2007)

Barriers (Tanriverdi and Iacono, 1998)	Microlevel	Macrolevel
Technical	**Technology** (hardware and software)	**Technology** (ICT infrastructure)
Behavioural	**Learning** (healthcare workers)	**Society**
Economical	**Core** (budget)	**Policy** (reimbursement models)
Organizational	**Core** (process integration and prioritization)	**Policy** (planning and promotion of telehealth)

4.3.2 Unified theory of acceptance and use of technology (UTAUT)

The UTAUT was the result of a study by Venkatesh *et al.* (2003) that synthesized eight theories/ models of technology use. Since then many extensions and adaptations of the UTAUT have been published. The most published version is presented in Figure 4.2.

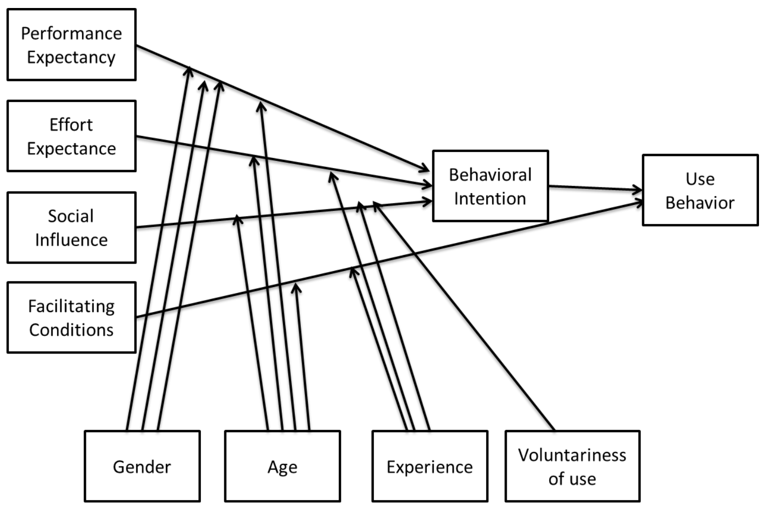

Figure 4.2: The unified theory of acceptance and use of technology (UTAUT) (Venkatesh *et al.*, 2003)

Dünnebeil *et al.* (2012) adapted the technology acceptance model (TAM), which is one of the theoretical frameworks underlying the UTAUT, to investigate determinants of physicians' technology acceptance for ehealth in ambulatory care. Their version of the TAM is shown in Figure 4.3.

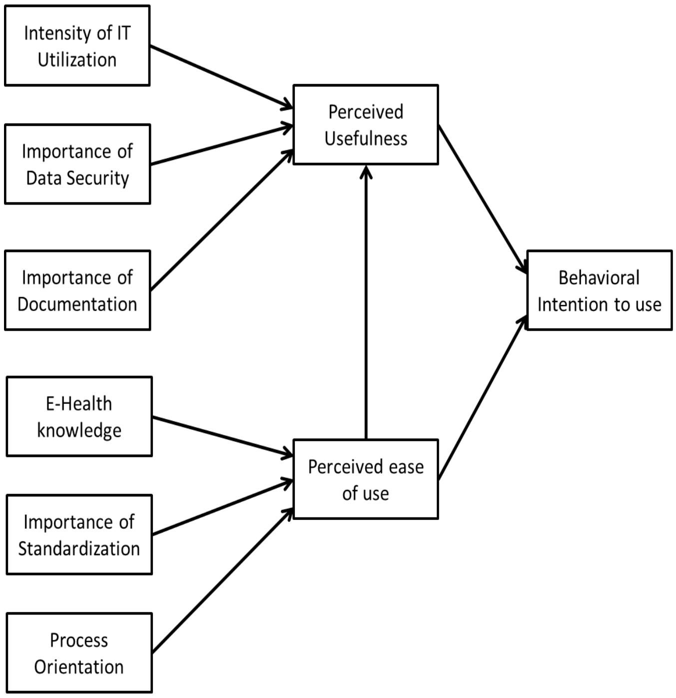

Figure 4.3: Technology acceptance model (TAM) for ehealth in ambulatory care (Dünnebeil *et al.*, 2012)

The UTAUT and TAM comprise a model, which indicates the interaction between different variables that determine the acceptance of technology, as indicated in Figure 4.2. This model is accompanied by a questionnaire which contains a list of statements related to each of these variables. For each statement respondents are presented with a Likert scale, according to which they are asked indicate the extent to which they agree or disagree, for example:

- I find [the technology under consideration] useful in my daily life.
- Using [the technology under consideration] helps me accomplish things more quickly.
- The [technology under consideration] is reasonably priced.
- The use of [the technology under consideration] has become a habit for me.

Dünnebeil *et al.* (2012) administered their questionnaire to 117 physicians and found that the perceived importance of standardization and the perceived importance of the current IT utilization were the most significant drivers for accepting electronic health services (EHS) in their practice.

Cilliers and Flowerday (2013) used the UTAUT to investigate user acceptance of telemedicine in the public health care system in the Eastern Cape. They concluded that "in general, the acceptance of Telemedicine in the Eastern Cape Department of Health is positive, but in order to integrate it into standard work practices, more must be done with regards to the promotion and education of telemedicine".

4.3.3 Design requirements satisfied by these frameworks?

Chipps and Mars (2012) and Van Dyk and Fortuin (2011) showed that the eHealth Readiness Assessment Tools are applicable to a typical telemedicine service. Cilliers and Flowerday (2013) did the same for UTAUT (DR 1 satisfied). Both allow the assessment of the service (DR 2 satisfied), but do not indicate further steps towards achievement of the target state (DR 3 not satisfied). These examples proved that the frameworks can be used as a basis for education and are easy to use by internal stakeholders from multiple disciplines (DRs 4 and 7 satisfied).

Durrani *et al.* (2012) and Van Dyk and Fortuin (2011) showed that eHealth Readiness Assessment Tools are suitable for a high level of abstraction to external stakeholders and strategic level decision-makers (DR 7 satisfied). Cilliers and Flowerday (2013) and Yarbrough and Smith (2007) did the same for the UTAUT. Both of these frameworks have questionnaires which can be followed intuitively by role players from multiple disciplines (DRs 5 and 6 satisfied). Neither of these frameworks are directly tied to standards, technologies or concrete implementation details (DR 8 satisfied).

Both of these frameworks rely on a Likert scale. A set of statements is provided on which respondents are asked to agree or disagree. These (capability) statements are mutually exclusive (DR 9). Due the specific focus of the UTAUT the capability statements are not collectively exhaustive in terms of all factors impacting the telemedicine service (DR 10 not satisfied). However, the eHealth Readiness Assessment Tools are probably collectively exhaustive (DR 10 satisfied).

Neither of the models in this section recognises a concept that resembles maturity or maturity levels (DR 11 not satisfied). Although the Likert scale suggests different levels of agreement, the (capability) statements themselves do not accumulate (DR 12 not satisfied).

Fraser *et al.* (2002) (Section 3.3) identified three categories for maturity models, namely (1) CMM-like models, (2) maturity grids, and (3) hybrids and Likert-like questionnaires. The focus of hybrids and Likert-like questionnaires is more on scoring specific statements of *good practice* rather than describing the overall levels of maturity (Mettler *et al.*, 2010). The same applies to the frameworks discussed in this section.

4.4 Retrospective Guidelines

Most frameworks in this chapter are based on theories from the world of science, for example Diffusion of innovation, Lewin's three phase model or Theories of technology acceptance. However, the frameworks that are discussed in this section are not based on a specific theory. They are lists that were compiled retrospectively, based on knowledge that was gained through the experience of developing, implementing and optimizing telemedicine services.

4.4.1 Seven core principles for the successful development of telemedicine services

Yellowlees (1997) identified seven broad principles, based on his experience in setting up three telemedicine systems in Australia. He intended these principles to be applicable to any telemedicine system, whether newly developed or in operation for some time. These principles are listed below:

1. Telemedicine applications as sites should be selected pragmatically, rather than philosophically.
2. Clinician drivers and telemedicine users must own the systems.
3. Telemedicine management and support should be from the bottom up rather than from the top down.
4. The technology should be as user-friendly as possible.
5. Telemedicine users must be well trained and supported, both technically and professionally.
6. Telemedicine applications should be evaluated in a clinically appropriate and user-friendly manner.
7. Information about the development of telemedicine must be shared.

He republished these principles eight years later, without any changes. Up until 2012, Yellowlees (1997, 2005) were cited in a total of 142 other publications on *Google Scholar*, of which 8 were during 2012. This shows that although published a relatively long time ago, they remain relevant.

4.4.2 Lessons in teledermatology service innovation

Finch *et al.* (2006) conducted a longitudinal study between 1997 and 2005 on twelve existing teledermatology services. They conducted a total of 68 interviews with service role players to identify those factors that contributed to these services becoming routine practice. These factors were organized into 5 themes:

Policy context: Policies should be formulated in such a way that it encourages, rather than discourages, telemedicine innovation. It is also important that the policies are translated into resources.

Evidence gathering, 'proving' safety and managing risk: The successful teledermatology services were those for which potential risks were acknowledged and safeguards built into the systems. Futhermore, such services emphasized the close monitoring of effects and outcomes, rather than formal, scientific, evaluation.

Perceived benefit and related commitment: There is a direct link between the willingness of role players to commit to new technology and/or methods and the benefit they are perceived to have.

Reconfiguring services: The focus should not be on the technology, but on the way in which the service is delivered.

Professional roles and boundary crossing: Together with changes in work procedures, clinicians need to make changes to their traditionally perceived professional roles.

Of the 43 publications who later cited Finch *et al.* (2006), eleven used these insights to gain an understanding of issues that impact on the success and sustainability of telemedicine initiatives.

4.4.3 Framework for assessing the health system challenges to scaling up mhealth in South Africa

Leon *et al.* (2012) recently published a framework that was developed after nineteen interviews with key roleplayers in the field of mhealth, the assessment of three local mhealth projects and a review of grey and indexed literature. This framework is presented in Table 4.3. Leon *et al.* (2012) defined four so-called dimensions, which are strongly reminiscent of the Barriers to the diffusion of telemedicine by Tanriverdi and Iacono (1998), although the authors did not refer to this. For each of these dimensions, a set of so-called capacity requirements is defined.

Table 4.3: Framework for assessing the health system challenges to scaling up mhealth in South Africa (Leon *et al.*, 2012)

Government stewardship: Is there a policy environment supportive of mHealth?

Strategic leadership: Strategic leadership is present through policy guidelines that promote alignment with strategic health goals, funding sources, common ICT standards and partnerships for collaboration nationally and internationally.

Learning environment: Government stewardship includes creating a learning environment, where projects are evaluated systematically and where collaboration and sharing of knowledge can contribute to a central repository of evidence on mHealth, which in turn can influence policy and practice.

Organizational: Is there a culture of and capacity for using information technology for management?

Capacity for implementation: The health system has the capacity, managerially and technologically, to successfully implement mHealth interventions. This includes assessment of ehealth readiness, a functional ICT environment and effective mechanisms for implementation, support and monitoring and evaluation.

Culture of information use: There is an organizational culture and tradition of using health information for management - to ensure that the increased access to electronic information is used for quality improvements in health services.

Technological: How useable, integrated and sustainable is the chosen technology?

Use-ability: The technology has ease of use, flexibility and durability and end users experience the new technology as benefiting their work.

Interoperability: Interoperability of information systems ensures there is smooth communication across technological and information platforms as well as smooth integration with existing work practices. Common standards (required for interoperable systems) are developed through consensus amongst the multiple stakeholders including health ministries, digital providers, health management, clinical staff, patients, and funders. The relative merits of open source versus proprietary software are addressed as this has implications not only for interoperability, but also for financial sustainability.

Privacy and security: Privacy and security of data is ensured. Additional regulations for protecting electronic data may be required to secure privacy of data.

Financial: Is adequate financial provision being made for the medium to long term use of mHealth?

Sustainable funding: Securing sustainable funding for large-scale implementation is a major requirement and requires clear business and funding plans. Plans should be realistic, especially as ICT projects may cost more and take longer than initially planned.

Cost-effectiveness: The cost-effectiveness of mHealth strategies is evaluated. mHealth interventions are weighed up against other priority and evidence-based interventions (in terms of the costs, resources and capacity requirements), and opportunity costs are routinely considered. Unintended consequences of introducing new technology within a weak health system are monitored to minimize negative effects.

4.4.4 Design requirements satisfied by these frameworks?

All of these guidelines were developed specifically with telemedicine services in mind. The Lessons in teledermatology can also be applied to other telemedicine specializations. mHealth, as it is referred to by Leon *et al.* (2012), fits this study's definition of telemedicine. Hence, DR 1 is satisfied within the context of all three sets of retrospective guidelines considered in this section.

These sets of guidelines do not describe, assess or provide advice based on assessment, as is required according to DRs 2 and 3. They can be used as a basis for education and explaining standards (DR 4 satisfied), although they do not set any standards as such. None of these provide an end-user interface (DR 5 not satisfied), nor is the level of granularity sufficiently appropriate to enable internal stakeholders to describe the telemedicine service at the detail level they are engaged with (DR 6 not satisfied). Furthermore, these frameworks do not describe or assess and thus fail to produce results of interest to external stakeholders (DR 7 not satisfied).

The frameworks by Yellowlees (2005) and Finch *et al.* (2006) are not directly tied to standards, technologies or concrete implementation details (DR 8 satisfied). However, Leon *et al.* (2012) distinguish, in their capability requirements, between open source and proprietary software.

Some issues are, nevertheless, re-emerging, for example the need for economically viable business models, the quest for evidence and sharing of best practices. However, each list also contains unique issues, for example the selection of a telemedicine site (Yellowlees, 1997), quality of services (Grigsby *et al.*, 2002), professional roles and boundary crossing (Finch *et al.*, 2006) and privacy and security (Leon *et al.*, 2012). Hence, neither DR 9, nor DR 10 are met.

The framework for assessing the health system challenges to scaling up mhealth in South Africa includes *capacity requirements* (Leon *et al.*, 2012), which do fit this study's definition for *capability statements*. These capability requirements were deduced from and structured according to this framework, but they do not relate to maturity levels and they also do not accumulate (DRs 11 and 12 not satisfied).

Although these sets of guidelines satisfy few design requirements, it proved to be useful to other telemedicine practitioners and researchers many of whom have cited these frameworks. Indeed, they could serve as valuable input for a new TMSMM.

4.5 Life Cycle Frameworks

It was explained in the previous chapter that organizational maturity often relates to an organizational life cycle, just as pshychological maturity typically relates to a life stage. However, (organizational) maturity does not always correlate with (organizational) life stages. In the same section the frameworks of Scott (2010), Broens *et al.* (2007) and Khoja *et al.* (2013*a*), were used to propose a typical telemedicine service life cycle (refer to Table 3.2 in the previous chapter). These three frameworks are considered in this section.

4.5.1 The layered telemedicine implementation model

Broens *et al.* (2007) conducted a systematic literature review to answer the question "why is it so difficult [to implement telemedicine] and what goes wrong?". In this study the Barriers to the diffusion of telemedicine publication (Tanriverdi and Iacono, 1998) is used as a theoretical framework in the identification of the so-called determinants for the successful implementation of telemedicine.

Broens *et al.* (2007) postulate that different determinants apply along the implementation life cycle and their layered implementation model was developed accordingly. The relationship between each implementation layer and its associated determinants (in brackets) is shown in Figure 4.4.

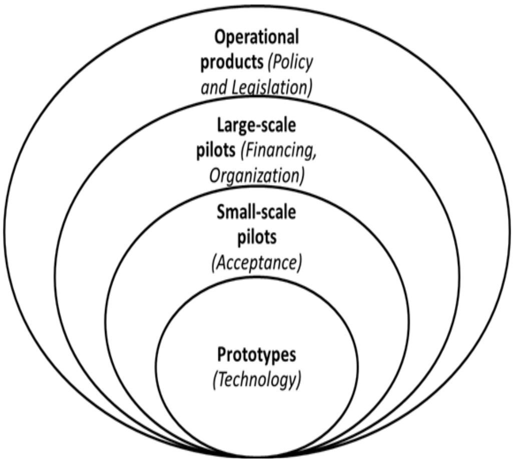

Figure 4.4: The layered telemedicine implementation model (Broens *et al.*, 2007)

At first, during the prototype phase, the focus was on the technological feasibility of the telemedicine service. Innovation acceptance (Section 4.2.2) and technology acceptance (Section 4.3.2) are the focus of some of the frameworks discussed earlier in this chapter. The extent to which this technology is accepted by the users and society determines, according to Broens *et al.* (2007), the success of the pilot phase.

As soon as the pilot projects are scaled up the financial and organizational considerations determine the success of the telemedicine service. Broens *et al.* (2007) explain that the research stages (prototype and pilot) are most often funded externally. Indeed, many telemedicine projects fail, because the financial sustainability beyond the research phases was not considered. Organizational issues include the definition of standards and protocols, as well as ensuring that the organization fits the new service rarther than making the technology fit the old organization.

Broens *et al.* (2007) describe a fully implemented service as an operational product. They identified policy and legislation as critical to this phase.

4.5.2 Pragmatic evaluation of ehealth interventions

Scott (2010) designed a so-called pragmatic evaluation to assist in the selection of the most appropriate approach to the evaluation of an ehealth intervention (refer to Figure 4.5). In the framework different evaluation methods are recommended, depending on the life cycle stage. During the early life cycles the focus is on formative and summative evaluation to prove the value of the intervention. In later life cycle stages, key indicators are used to facilitate continuous quality improvement (CQI).

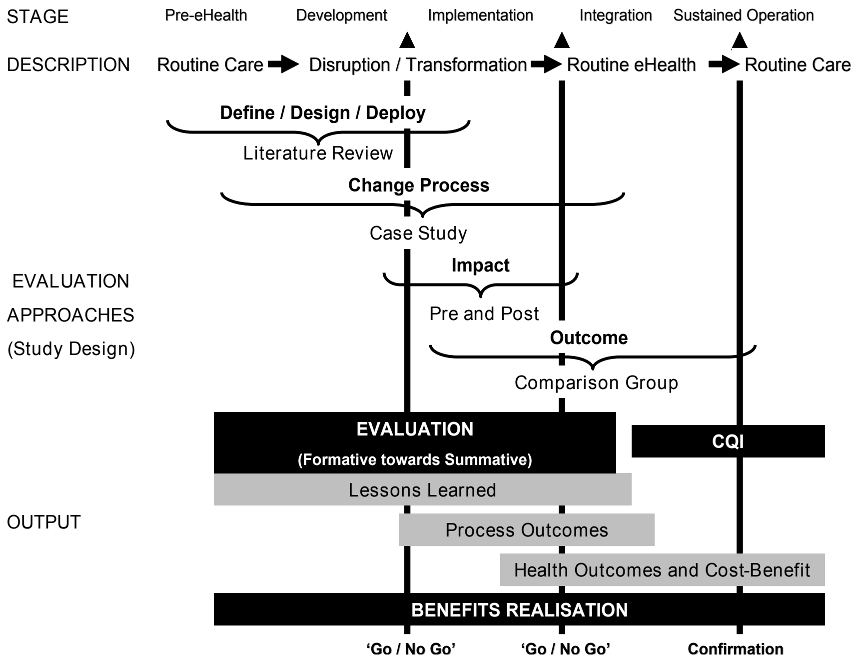

Figure 4.5: Framework for the pragmatic approach to the evaluation of an ehealth interventions (Scott, 2010)

4.5.3 The Khoja-Durrani-Scott (KDS) evaluation framework

The Khoja-Durrani-Scott (KDS) evaluation framework (refer to Table 4.4) was developed as a PANACeA (PAN Asian Collaboration for Evidence-based ehealth Adoption and Application) output by some of the authors who developed the ehealth readiness assessment tools.

The significance of this framework lies in the fact that it acknowledges the need for different assessment strategies throughout this implementation life cycle. This framework has several dimensions. The first two dimensions can be seen in Table 4.4: Column headings are the stages of the ehealth life cycle and the themes

Table 4.4: The Khoja-Durrani-Scott (KDS) evaluation framework

	Stages of the ehealth life cycle			
Themes of Evaluation	**Development**	**Implementation**	**Integration**	**Sustained Operation**
Health Services	Ongoing and periodic assessment of health status, existing services needs and opportunities	Improved diagnosis and treatment of disease conditions	Health impact leading to change in disease status	Health impact showing change via indicators
Technology	Development cost, availability, affordability	Interoperability	Appropriate in a variety of conditions	Scalability
Economic	Affordability	Cost-utility	Cost-benefit	Improved DALYs
Behavioral and Socio-technical	Human resource factors	Strategy for e-health implementation	Strategy for broader e-health adoption	Adoption/ adaption of technology on a wider scale
Ethical	Prioritizing ehealth over other issues	Sensitive to socio-cultural issues	Broader perspective on security, liability, licensure and reimbursement	Security
Readiness and Change	Plan for change management	Training of staff, including clinical and management staff	Effective change management (maintenance)	modification, improvement, customization
Policy	Policies for change management	Limited changes in organizational and national policies	Policies changes to facilitate broader adoption	Healthy public policy and organizational practice.

for evaluation are listed as row headings. Secondly, the themes for evaluation are listed as row headings.

For each of the 4 stages of the ehealth life cycle (taken from Scott, 2010) and for each of the 7 themes of evaluation (28 cells in total), Khoja *et al.* (2013*a*) defined desired outcomes or outcome charateristics. Some examples of these outcomes are indicated in Table 4.4.

A further dimension of the KDS-framework does not appear in Figure 4.4, but is available on the Internet (Khoja *et al.*, 2013*b*) in the form of a collection of evaluation questionnaires. These questionnaires consist of a series of statements, linked to a Likert scale and are similar to the ehealth readiness tools. While the former was scaled from 'not-prepared' to 'prepared' (Khoja *et al.*, 2007), the scaling of the KDS-framework is more specific: 'unsatisfactory - below expectations - meet expectations - above expectations - extraordinary'.

Three sets of questionnaires are available, depending on the viewpoint of the respondent. Also similar to the ehealth readiness assessment tools, a few sets of questionnaires are developed. The appropriateness set is determined by the viewpoint of the assessor, i.e. (1) manager or (2) healthcare provider. A third viewpoint category is added to the KDS, namely (3) client.

4.5.4 Design requirements satisfied by these frameworks?

All three of these frameworks were developed specifically for telemedicine or ehealth (of which telemedicine is a subset). All three frameworks can be used for education and explanation to a multidisciplinary audience. None of these are directly tied to any standards, technology or implementation details. Hence, DRs 1, 5 and 8 are satisfied. However, the layered implementation model (Broens *et al.*, 2007) does not contain any statements/descriptions that can be defined as capability statements (DRs 9,10,11 and 12 are not satisfied).

The Pragmatic evaluation of ehealth interventions offers approaches to the assessment of different stages. However, only the KDS evaluation framework includes a tool (Likert-like scale) for the assessment of the telemedicine service (DR 2 and DR 5). The assessment entails that the participant(s) indicates on a Likert scale, the degree to which they agree or disagree but does not necessarily equip the analyst to derive actions to enhance maturity upon completion (DR 3 not satisfied). It does, however, provide the interaction with internal and external stakeholders required by DR 6 and 7.

Like the eHealth readiness assessment tools (Khoja *et al.*, 2007) the questionnaires of the KDS evaluation framework contain a series of (capability) statements, which are associated with a Likert scale. These statements are probably mutually exclusive (DR 9) and collectively exhaustive (DR 10). Although the statements are organized according to different life cycle stages they do not relate to maturity levels and they do not accumulate (DRs 11 and 12 not satisfied).

Based on the fact that the KDS-framework satisfied DRs 1,2,4,5,6,7,8,9 and 10, it can be said to serve as a reference model for telemedicine services. The three design requirements that are not satisfied by the KDS-framework (DRs 3,11 and 12) are those design requirements that describe typical patterns in the development of organization capabilities, which together form a desired or logical path from initial to target maturity state. As is the case in the ehealth readiness frameworks (Section 4.3), the KDS falls within the category of hybrids and Likert-like scales (Fraser *et al.*, 2002), but it does not qualify as a maturity model.

4.6 Maturity Models

In this section existing maturity models within the context of telemedicine services are considered.

4.6.1 NHS infrastructure maturity model (NIMM)

The NIMM is an IT infrastructure maturity model that was developed by the NHS Technology Office together with a number of different NHS IT Organizations in the United Kingdom. During its development, the NHS team worked closely with Atos Healthcare, a consultant company, helping to define and develop the NIMM (Savidas, 2009). The NIMM consists of two sub-models, each with its own categories:

Business sub-model: (1) procurement, (2) financial management, (3) business alignment, (3) people and skills, and (5) principles, standards, procedures and guidelines

Technology sub-model: (1) end-user devices, (2) common applications and services, (3) operating systems, (4) infrastructure and hardware platforms, (5) principles, standards, procedures and guidelines, and (6) IT security and information governance

4.6.2 The PACS maturity model

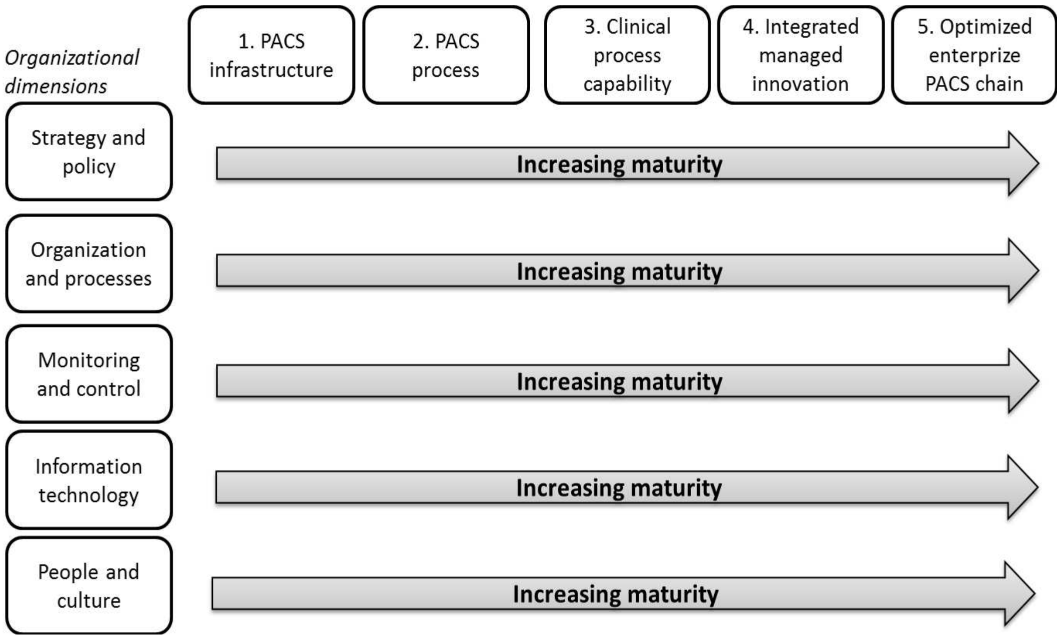

Figure 4.6: PACS maturity model (Van de Wetering, 2009)

Around the time of NIMM's development, Van de Wetering and Batenburg (2009) recognized the potential benefit of maturity models for healthcare services. In accordance with teleradiology as their specific area of focus, they developed a maturity model for Picture Archiving and Communication Systems (PACSs). Van de Wetering (2009) defined five dimensions and five maturity levels. The dimensions are as follows:

Strategy and policy include organization of strategy and policy procedures.

Organization and processes address processes as a basic principle of organizational development.

Monitoring and control include financial and non-financial management control.

Information technology (IT) concerns IT management and development processes.

People and culture reflects value and significance of employees for an organization.

Van de Wetering (2009) formulated 6 capability statements for each of the five dimensions and two statements each for maturity level 3, 4 and 5. According to him, "statements for maturity level 1 and 2 for each organizational domain are omitted for practical reasons and due to the fact that all Dutch hospitals [where the study was executed] have a PACS implemented (initial maturity level). Level 2 can be deducted from assigned scores to level 3 statements."

4.6.3 eHealth maturity categories for health information systems

The 2012 eHealth Strategy (Government, 2012) of the South African Department of Health makes reference to the so-called eHealth maturity categories which are used in a landscape analysis of health information systems (HISs) in developing countries (Government, 2012):

1. "paper-based systems for collecting district health indicators,
2. optimisation of paper systems through simplifying indicators and reducing duplication,
3. migration of traditional district health information systems to electronic storage and reporting,
4. introduction of operational ICT systems as a source of data for HIS,
5. a fully comprehensive and integrated national HIS."

4.6.4 Design requirements satisfied by these frameworks?

The detailed content of the NIMM is not available in the public domain. However, based on the information provided by the United Kingdom Health and Social Care Information Centre (NHS, 2013), it is assumed that the NIMM adheres to all design requirements, except DRs 1 and 2. The reason for this is that the application domain of this model is ICT within a healthcare system, but with no specific reference to telemedicine or even ehealth.

Similarly, the PACS maturity model probably satisfies DRs 3 to 7 and 9 to 12. (DR 8 is not satisfied, as the PACS MM includes reference to specific technology.) However, it is directed at a specific teleradiology application and cannot be used to describe or assess any telemedicine service (DR 1 and 2). Also, Van de Wetering (2009) specifically envisaged the PACS MM to be applied to Dutch hospitals. For this reason he found it necessary to define capability statements for maturity levels 1 and 2.

The maturity scale of the ehealth maturity categories for health information systems is cumulative and has one (capability) statement for each level (DRs 11 and 12). However, none of the other design requirements is satisfied. This framework is therefore only one-dimensional and limited to health information systems (HISs). The only value it holds, is that it serves as basis for comparison between the countries considered in the report. South Africa is placed at stage 3. In the 2012 eHealth Strategy (Government, 2012), it is recognized that some provinces within South Africa are at stage 2, others at stage 4, while some regions and districts within one province can vary between 1,2 and 3.

4.7 Other Models

This section considers two frameworks that were specifically developed for the evaluation of telemedicine services, but which do not fit in any of the previous sections.

4.7.1 Comprehensive model for evaluating telemedicine

This model is based on the theories of transactional economics, also referred to as transaction cost economics, and has three dimensions, as indicated in Figure 4.7. Hicks *et al.* (2004) call their model *comprehensive* because of its three-dimensional approach which, according to them, ensures that the myriad of issues related to telemedicine services are considered.

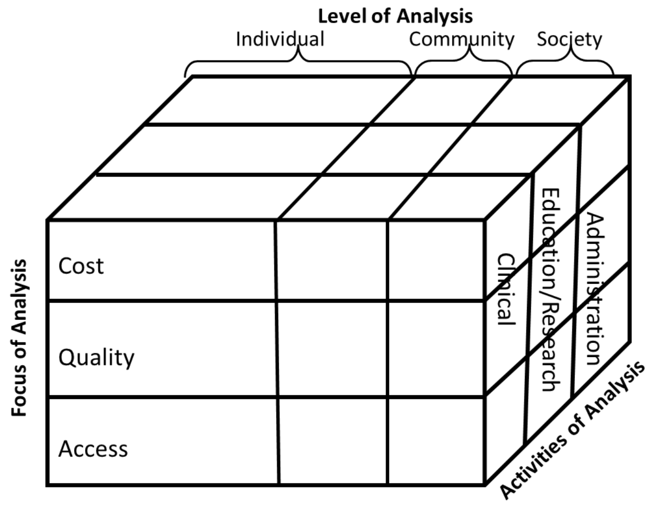

Figure 4.7: Comprehensive model for evaluating telemedicine (Hicks *et al.*, 2004)

Level of analysis: Each of the three broad categories (individual, community and society) comprises multiple elements of which some examples are indicated on Figure 4.7. "Conclusions regarding the acceptability of telemedicine may vary substantially accross the three levels, since benefits and costs may accrue to entities outside the immediate transaction" (Hicks *et al.*, 2004).

Focus of analysis: This dimension considers the often conflicting considerations of cost, quality, and access to health care.

Activities of analysis: Telemedicine services are mostly directed towards clinical examinations, consultations, discussions and other clinical purposes. It is also recognized that telemedicine service infrastructure is also used for education, research and administration.

This model satisfies DR 1, since it provides a framework within which a telemedicine service can be positioned and described. But it is unclear how the service is assessed within this framework. Consequently, no further suggestions can be derived, no assessment methodology to follow intuitively, nor results to aggregate (DRs 2, 3, 5 and 7 not satisfied). However, this framework can be used as basis for education and explaining standards (DR 4). Role players from multiple disciplines can use the TMSMM on their level, but not necessarily for assessment purposes (DR 6 partially satisfied).

Hicks *et. al*'s model is not tied to any standards, technologies or concrete implementation details (DR 8 satisfied). It does not contain additional detail concerning outcomes, capability statements or evaluation criteria, which disqualifies DRs 9, 10, 11 and 12.

4.7.2 Model for assessment of telemedicine applications (MAST)

The development of this model is based on results from workshops with stakeholders and users of telemedicine, a systematic literature review (Ekeland *et al.*, 2011) and the European Health Technology Assessment Network (Lampe and Mäkelä, 2012) a core model for interventions.

According to Kidholm *et al.* (2012) MAST defines the relevant assessment as a multi-disciplinary process that summarizes and evaluates information about the medical, social, economic and ethical issues related to the use of telemedicine.

Kidholm *et al.* (2012) also acknowledge that empirical tests of the usability of MAST are needed to ensure its usefulness. Empirical studies would have been carried out from 2010 to 2013 in the Renewing Health project initiated by the European Commission, but no results of any of these are available in the public domain. Furthermore, only a draft version of the MAST manuals is available (MethoTelemed, 2012) and the official MAST website (MAST, 2013) is under construction.

The MAST toolkit (MAST, 2013) comprises an Excel document with seven sheets, one each per domain (Health Problem, Safety, Clinical Effectiveness, Patient Perspectives, Economic Aspects, Organizational Aspects, Socio-cultural and Legal Aspects). Each of these seven sheets has a list of statements or questions, which the participant must either indicate as "true" or "false". The relationship between these statements/questions is unclear and no indication is given of further actions, based on this assessment.

The MAST (Kidholm *et al.*, 2012) considers a telemedicine service to be mature if the application has been used on a sufficiently large number of patients for most problems to have been addressed. Then the service is in the so-called *steady state*. This state is comparable with the generic CMM maturity level 3 (define). Only then can an assessment based on MAST be executed. Similarly, in terms of the CMM maturity levels, a process should only be quantitatively managed (level 4) once the process is standarized.

Even if enough information were available to be able to declare that the MAST is an effective reference model for telemedicine services (DRs 1,2,4,5,6,7,8,9,10), it is limited to the measurement (maturity level 4) of defined (maturity level 3) telemedicine services. As such, it definitely does not satisfy DRs 3, 11 and 12.

4.8 Conclusion

Table 4.5 summarises the requirements mapping analysis. Frameworks are listed that were discussed in prior sections which were included due to their potential to satisfy the design requirements. The 12 columns on the right hand side each represent a design requirement. It is indicated against each framework whether the design requirements are satisfied, based on the information discussed earlier in this chapter.

Table 4.5: Design requirements satisfied by existing frameworks

Ref.	**Framework**	Design requirements addressed											
4.2.1	Barriers to the diffusion of telemedicine	1	x	x	4	x	6	7	8	x	x	x	x
4.2.2	Influences on the diffusion of telemedicine	1	x	x	4	x	6	7	8	9	x	x	x
4.3.1	E-health readiness assessment tools	1	2	x	4	5	6	7	8	9	10	x	x
4.3.2	Unified theory of acceptance and use of technology (UTAUT)	1	2	x	4	5	6	7	8	x	9	x	x
4.4.1	Seven core principles for the successful development of telemedicine systems	1	x	x	4	x	x	x	8	x	x	x	x
4.4.2	Lessons in teledermatology service innovation	1	x	x	4	x	x	x	8	x	x	x	x
4.4.3	Framework for assessing the health system challenges to scaling up mhealth in South Africa	1	x	x	4	x	x	x	x	x	x	x	x
4.5.1	The layered telemedicine implementation model	1	x	x	4	x	x	x	8	x	x	x	x
4.5.2	Pragmatic evaluation of ehealth interventions	1	x	x	4	x	x	x	8	x	x	x	x
4.5.3	The Khoja-Durrani-Scott (KDS) evaluation framework	1	2	x	4	5	6	7	8	9	10	x	x
4.6.1	NHS Infrastructure maturity model (NIMM)	x	x	3	4	5	6	7	8	?	?	?	?
4.6.2	The PACS maturity model	x	x	3	4	5	6	7	x	9	10	x	12
4.6.2	eHealth maturity categories for health information systems	x	x	x	x	x	x	x	x	x	x	11	12
4.7.1	Comprehensive model for the evaluation of telemedicine	1	x	x	4	x	6	x	8	x	x	x	x
4.7.2	The model for the assessment of telemedicine services (MAST)	1	2		4	5	6	7	8	9	10	x	x

The objective of this chapter was to search for a framework that satisfies all the design requirements of a maturity model for telemedicine services. The following questions were asked:

Research Question 4.1: What telemedicine reference models, frameworks or guidelines exist?

Research Question 4.2: Which design requirements are satisfied by each of the respective frameworks?

Research Question 4.3: Do any of these frameworks satisfy all the design requirements?

If there was the slightest possibility that a design requirement would be met, it has been indicated as such. For example, *statements* (Khoja *et al.*, 2007, 2013*a*) and *capability requirements* (Leon *et al.*, 2012) were viewed as *capability statements* for the purposes of the mapping exercise. Futhermore, in the case of NIMM and MAST, not enough information was available to to satisfactorily confirm that certain design requirements had been met. However, any assumptions made, were in favour of these frameworks, based on the claims by the developers.

In addition, DR 1 specifically refers to telemedicine services as they are defined for the purposes of this study (healthcare services delivered over a distance). Some frameworks, e.g. the eHealth Readiness Assessment Tools, have a wider scope, including all ICT supported healthcare services. In these cases DR 1 was indicated as satisfied.

The requirements mapping analysis (Table 4.5) revealed that none of these frameworks satisfies all the design requirements. However, a few of the frameworks satisfy a sufficient number of design requirements to be considered as reference models for telemedicine and/or ehealth.

These frameworks are the eHealth readiness assessment tools, the Unified theory of acceptance and use of technology (UTAUT) as it is applied to telemedicine, the KDS evaluation framework and possibly the model for the assessment of telemedicine. However, none of these frameworks describe typical patterns in the development of organizational capabilities and none depict a sequence of stages toward the desired state (DRs 3, 11 and 12), as can be expected from a maturity model (De Bruin *et al.*, 2005; Solli-Saether and Gottschalk, 2010; Pöppelbuß *et al.*, 2011).

On the other hand, the frameworks that were considered in Section 4.6 do satisfy the requirements related to maturity and maturation paths, but they are either restricted to a specific telemedicine application and specific implementation details

(PACS maturity model) or encompasses a larger health system (NHS infrastructure maturity model), at the cost of the detail needed to assess a telemedicine service.

This study originated from the following research problem (Section 1.1): many telemedicine services which showed initial success, are not sustained. Many mistakes in the implementation of telemedicine services are repeated over and over again and only a few good practices are replicated. There is a need for a reference model that can be used to assess telemedicine services and which can guide and educate stakeholders towards the optimization of these services.

Some of the models presented in this section can be used to assess a telemedicine service. Some models provide guidelines for the implementation of telemedicine services and some allow the assessment of processes and guide accordingly towards a desired state of maturity, but are not specifically directed towards telemedicine services. It is concluded that a maturity model for telemedicine services does not exist.

Given the urgent need for effective telemedicine services that could provide more efficient health care, there is clearly a need for such a model. Over the next three chapters, the development of a new telemedicine service maturity model (TMSMM) is described.

Chapter 5

The Conceptual Maturity Model

The purpose of this study is to find or develop a maturity model for telemedicine services that can be used to describe and assess telemedicine services and guide and educate stakeholders towards the optimization thereof.

The conclusion of the previous chapter was that none of the existing frameworks from the state of the art satisfies all the design requirements. Hence, the next objective is to develop a new telemedicine service maturity model (TMSMM) that can do so. The development of this model is described over the next three chapters, as indicated by Figure 5.1. This chapter describes the model development approach as well as the development and design of the conceptual TMSMM.

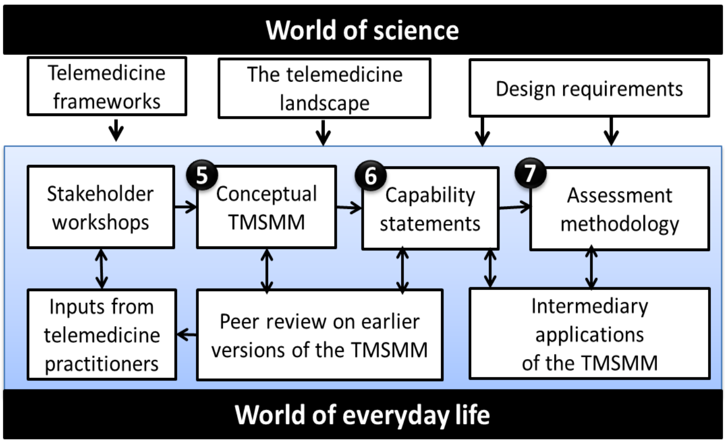

Figure 5.1: Research roadmap: Development of the TMSMM

5.1 Iterative Design Process

In Chapter 3 it was established that an iterative top-down approach is typically followed in the development of maturity models (refer to Section 3.5). Such an approach was followed in the development of the TMSMM. This approach resembles the frameworks of Solli-Saether and Gottschalk (2010), De Bruin *et al.* (2005) and Von Wangenheim *et al.* (2010).

Figure 5.1 shows the iterative design process, specific to this study. Inputs from both the world of science (the telemedicine landscape and other frameworks) and the world of everyday life (stakeholder workshops and peer review) are used in an iterative way.

5.1.1 Top-down approach

When developing a maturity model, either a bottom-up or a top-down approach can be followed. In a bottom-up approach capabilities are defined first and then, based on these definitions, maturity levels are defined and the rest of the maturity model is constructed. With a top-down approach (De Bruin *et al.*, 2005), the maturity model is first conceptualized in terms of dimensions (Section 5.2 and Section 5.3) and maturity levels (Section 5.5). The capability statements are then formulated within the frame of the conceptual model (Chapter 6).

The latter approach was followed in this study. Research questions 5.1, 5.2 and 5.3 applies to this process and are addressed in this sequence. An entire chapter is devoted to each of these questions:

Research Question 5.1: What conceptual design will address the design requirements? (Chapter 5)

Research Question 5.2: Which detailed descriptions in terms of capability statements, will address the design requirements? (Chapter 6)

Research Question 5.3: Which assessment methodology will address the design requirements? (Chapter 7)

5.1.2 Inputs from the world of everyday life

For purposes of the development of the conceptual TMSMM inputs from the world of everyday life are from stakeholder workshops and peer review.

5.1.2.1 Stakeholder workshops

Between June 2011 and December 2011, a series of workshops was held in South Africa. Representatives included healthcare workers (e.g., specialists, radiologists, radiographers and nurses), as well as persons responsible for the development, implementation and maintenance of hospital information and communication technology (ICT). Most of the workshop participants were from the public health sector.

The first day of these workshops was used to educate representatives about telemedicine. On the second day, workshop delegates used earlier versions of the TMSMM to describe and assess telemedicine services within their context. In doing so, they gained an appreciation for all of the aspects that determine telemedicine success and learned from each other about the clinical and technical detail concerning their telemedicine service. Some outputs from these workshops are added to Appendix E.

It was also explained to the participants that the framework used during the workshop is in a process of continuous involvement. They were informed that their inputs may be used to inform future versions of this framework. All participants consented in writing to be involved in this way, provided that neither their own identities nor the identities of their institutions are revealed.

5.1.2.2 Peer reviewed publications

All of the peer reviewed publications that resulted from this study are included in Appendix A. The interaction between these stakeholder inputs and the peer review process are described below:

Concept development iteration 1: The first of these workshops was held on 13 and 14 June 2011 at the Universitas Hospital, Bloemfontein, involving 4 clinicians and 4 technicians from various provincial hospitals within a 200 km radius of Bloemfontein. The results were presented at the *International Conference on Industrial Engineering, Systems Engineering and Engineering Management (Stellenbosch)*, which was held in September 2011 (Van Dyk *et al.*, 2011) (Appendix A.2.2).

The purpose of this paper was to develop a framework that can be used to measure and manage the capability of a health system to sustain health care delivery after the pilot phase of a telemedicine project. At that point in time maturity models were not yet identified as type of model that can possibly address this purpose. Four existing frameworks were used as input to this maturity model, namely the ISO 15288 Systems Engineering Life Cycle Standards, the ISO/IEC 15504 Software Process Improvement and Capability Determination (SPICE), eHealth Readiness Instrument for developing countries and the Layered Telemedicine Implementation Model. The output was a three dimensional model. The relation between the dimensions of this framework and the eventual TMSMM is described in sections 5.2.1, 5.3.1 and 5.5.1.

Concept development iteration 2: The next conference paper (Van Dyk *et al.*, 2012*a*) presebte data from two provincial workshops (Appendix A.1.2). These workshops were held in East London (3 and 4 August 2011 with 12 participants) and Vryburg (30 and 31 August with 25 participants).

This was the first research output which included the term *maturity model* in the title. In additional to the theoretical frameworks considered in the first paper, this iteration also considered the PACS Maturity Model and the NHS Maturity Model. The output was a three dimensional model. The relation between the dimensions of this framework and the eventual TMSMM is described in sections 5.2.2, 5.3.2 and 5.5.2.

Concept development iteration 3: On 8 and 9 December 2011 a workshop was held in Port Elizabeth, involving 5 technicians and 4 clinicians. Data gathered during this workshop was used as input for a full journal article (Van Dyk and Schutte (2012), Appendix A.5).

The full journal article where produced for a special edition of this journal upon invitation of the conference organizers of the first paper and on merit of the potential of the first paper. The most significant difference between models presented in the respective papers is with regards to the service dimension as explained in section 5.2.3. This paper also included a few case studies.

Concept development iteration 4: During 2012 this conceptual model was used in a few studies on specific telemedicine applications, two of which were shared at and published in proceedings of international conferences (Van Gemert-Pijnen *et al.*, 2011; Triegaardt and Van Dyk, 2012; Triegaardt, 2013). In the execution of these studies, insights were gained concerning the conceptual model, which lead to further improvements to the construct. The iteration is concluded with a chapter publication (Van Dyk and Schutte, 2013) (Appendix A.4.2).

This chapter was introduced along with some background on maturity models to provide the rationale for using maturity models as reseach artefact was provided. The scope of the chapter allowed for the inclusion of detailed domain-specific maturity scales and capability statements for the microlevel processes. The relationship between the dimensions of this framework and the eventual TMSMM is described in sections 5.2.4, 5.3.3 and 5.5.2.

Further iterations were executed in the development of the capability statements (Chapter 6) as well as the end-user interface (Chapter 7) and will be elaborated upon in the respective chapters.

5.1.3 Inputs from the world of science

From the world of science, further inputs to the iterative design process include the existing telemedicine frameworks (Chapter 4) as well as the design requirements (Chapter 3). The influence of specific frameworks as well as the intentional consideration of design requirements in each iteration of the development of the conceptual TMSMM are described in the remainder of this chapter.

5.1.4 Iterative development of dimensions

As is described in Section 3.4.3, a maturity model consists of one or more dimensions. From the first development iteration, the design of the TMSMM included two dimensions. Despite many iterative changes to the categories of each of these respective dimensions, no dimension was added or taken away. Table 5.1 shows the iterative development of these two dimensions. In the sections that follow, each of these dimensions is elaborated upon.

Table 5.1: Iterative development of dimensions

Concept development iteration	**Name of model**	**Domain dimension** (Section 5.2)	**Telemedicine service dimension** (Section 5.3)
1	A systems engineering approach to telemedicine implementation	Success Determinants	Systems Engineering Processes
2	A maturity model for telemedicine implementation	eReadiness Categories	Telemedicine Process
3	The Telemedicine Maturity Model (TMMM)	Maturity Categories	Telemedicine Process
4	The telemedicine service maturity model (TMSMM)	Domain Dimension	Telemedicine Service Dimension

5.2 Domain Dimension

A domain is a sphere of activity, concern, or function (Merriam Webster, 2013) and represents perspective from which to view the use, consequences and implications (Kidholm *et al.*, 2012) of the entity under consideration.

5.2.1 First iteration

Figure 5.2 shows the development of the *Domain* dimension. The domains for the first two iterations (Van Dyk *et al.*, 2011) were primarily derived from the work of Broens *et al.* (2007) and Khoja *et al.* (2007). These frameworks were elaborated

Research iteration 1	*Research iteration 2*	*Research iteration 3*	**Research iteration 4**		
Success Determinants	**eReadiness Categories**	**Maturity Categories**	**The Domain Dimension**		
			Micro-level	**Meso-level**	**Macro-level**
Policy and legal issues	Policy and legal issues				
Technological readiness	Technology/ maintenance	Man: Users →	Man	Man	Man
Diffusion and acceptance	Individual users	Machine: Technology →	Machine	Machine	Machine
External interaction	Organisational processes		Material	Material	Material
Internal organization	Community interaction/ involvement	Method: Procedures Method: Policies →	Method	Method	Method
Financial sustainability	Planning and financial sustainability	Money: Finances →	Money	Money	Money

Figure 5.2: Iterative development of the TMSMM domain dimension

upon in Section 4.5.1 and 4.3.1 respectively. In this iteration, this dimension was labeled *Success Determinants* after the terminology used by Broens *et al.* (2007).

5.2.2 Second iteration

At the start of the study, maturity models had not yet been identified as artefacts which could address the research problem. However, from the second iterations onward, the development of a maturity model was purposefully pursued. For this reason maturity models within the healthcare domain were specifically consulted. Two models were included at that stage, namely the NHS infrastructure maturity model (NIMM) (Savidas, 2009) and the PACS maturity model (Van de Wetering and Batenburg, 2009).

As a result, a few aspects were added to this dimension, for example technology maintenance and reimbursement of individual users. Apart from this, the changes to this dimension primarily involved the rearrangement of ereadiness categories (as it was called during that iteration), based on inputs during stakeholder workshops.

5.2.3 Third iteration

In Chapter 4, it was shown how the Barriers to the diffusion of telemedicine (Tanriverdi and Iacono, 1998) re-emerged as a theme in other frameworks (Broens *et al.*, 2007; Khoja *et al.*, 2007; Van de Wetering, 2009; Leon *et al.*, 2012; Savidas, 2009). This became evident during the third iteration, as more information from the world of science was consulted.

Reference is often made to the so-called alphabet soup of the business world. For example: the 4Ps of marketing, the 5Ps of strategy, the 4Ps of healthcare, the 5Ss of lean manufacturing, the 4Ms, 5Ms, 6Ms and 7Ms of manufacturing, and the list continues. The value of these models (representations of the real world) lies in their simplicity and re-usablity. The fact that these concept groupings are applied repetitively and to a variety of contexts is indicative of its validity and generalizability.

The relation between the categories of Tanriverdi and Iacono (1998) and the 4Ms of manufacturing are shown in Table 5.2. This relationship became clear during the third iteration's stakeholder workshops. The *Domain* dimension for this iteration was structured accordingly (compare Figure 5.2 with Table 5.2)

Table 5.2: Relationship between the 4Ms of manufacturing and the Barriers to the diffusion of telemedicine

4Ms of Manufacturing	Barriers to the Diffusion of Telemedicine
Man	behavioral barrier
Machine	technical barrier
Method	organizational barrier
Money	economical barrier

5.2.4 Fourth iteration

It may seem inappropriate to apply the 4Ms of manufacturing to the domains of the TMSMM. However, the generic description of a manufacturing process is similar to a telemedicine service: The telemedicine service entails the sourcing and acquisition of raw material (raw patient data and information) at the right place, the right time, and according to the right specification. This information is then reworked into a useful product (such as diagnosis and treatment prescription), which only has value if it reaches the external customer (patient) or internal customer (referring healthcare worker) at the right place, the right time, and according to the right specification.

The conversion of data into information (the *material* of the telemedicine service) and the transmission thereof, is the key to the telemedicine service. Hence, during the fourth and final iteration in the development of the conceptual model, the 4Ms were expanded to the 5Ms to include *Material* (data/information). It was also during the fourth iteration that *Service* dimension was expanded to include meso- and macro-level processes, which is the reason that two dimensions are shown for the fourth iteration in Figure 5.2.

5.3 Service Dimension

The way in which the service dimension evolved to this point is illustrated by Figure 5.3.

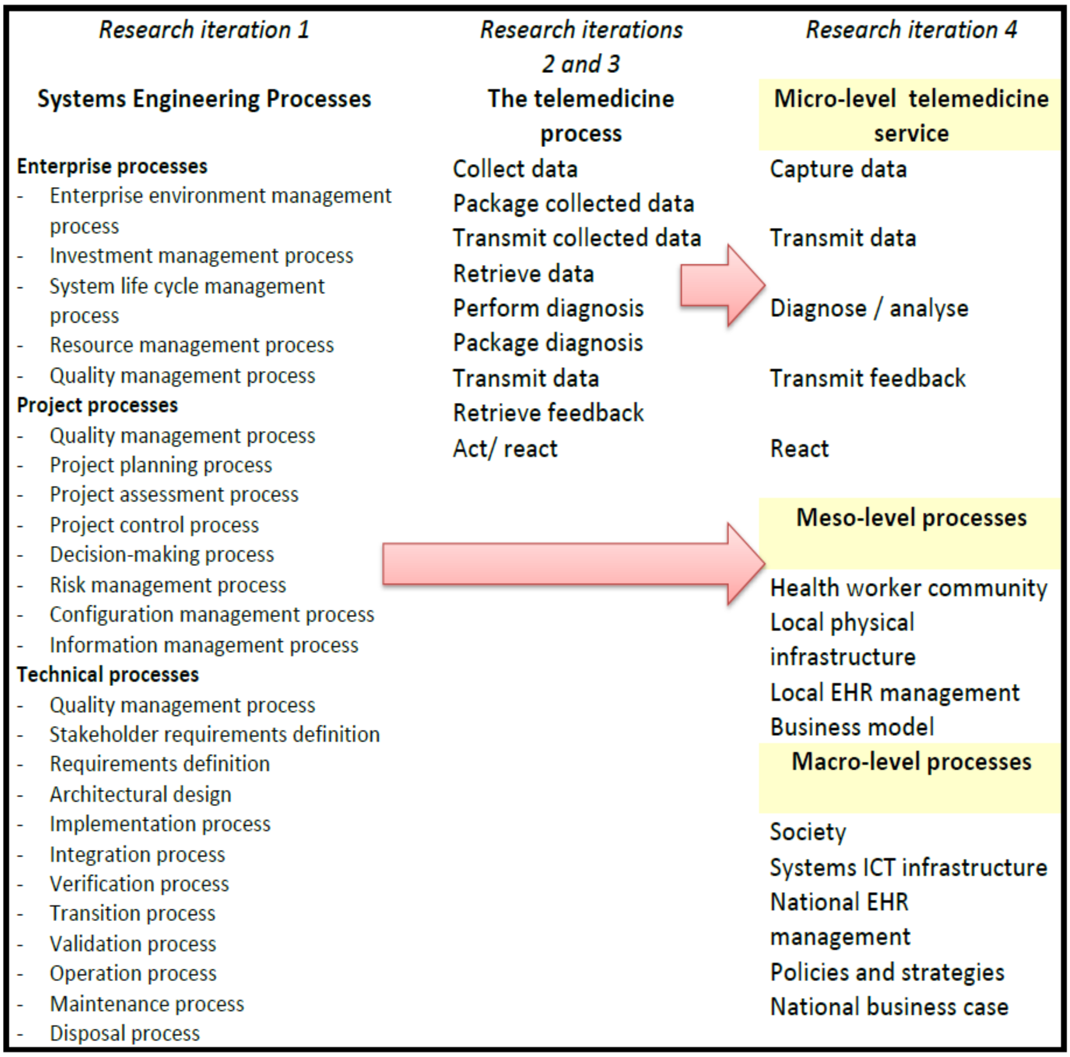

Figure 5.3: Iterative development of the TMSMM service dimension

5.3.1 First iteration

In the first iteration of the TMSMM this dimension was labelled *Processes*. At that stage it was already clear that a systems approach is needed to develop and sustain successful telemedicine services. Hence, the ISO 15288 Systems Engineering Life Cycle Standards were used.

Another reason why these standards were deemed appropriate at that stage is that the Software Process Improvement Capability Determination (SPICE) can provide maturity level and capability statements, which are often used in conjunction with the ISO/IEC 15288 standards.

5.3.2 Second and third iterations

The ISO 15288 is multidimensional in itself. The complexity caused by adding this as dimension was the single greatest point of critique for this first iteration. In response to the critique, this dimension was deliberately replaced with a simple generic telemedicine process, as shown in Figure 5.3. The new label for this dimension was *Telemedicine Process* (Van Dyk *et al.*, 2011). From the second to the third iterations this dimension did not change at all.

5.3.3 Fourth iteration

As a consequence of this replacement, some higher level processes and systems, crucial as determinants for successful telemedicine implementation unfortunately had to be excluded. Hence, in the final version of the TMSMM the telemedicine service dimension combines the systems engineering intention of the first iteration, with the micro-level focus of the telemedicine process of the second and third iterations. In this fourth iteration, three layers of telemedicine services are defined and labelled micro-level telemedicine processes, mesolevel telemedicine processes and macro-level telemedicine processes, respectively.

5.3.3.1 Microlevel telemedicine processes

In the final TMSMM, the microlevel telemedicine service is broken up into five generic processes, which are applicable to any telemedicine service. Telemedicine is by definition the delivery of healthcare service *(medicine)* over a distance *(tele)*.

The four micro-level processes are derived accordingly:

1. Data is captured (Capture Data),
2. then transmitted (Transmit Data),
3. to where the data is analysed and converted into useful information (Diagnose/ Analyze),
4. which is then transmitted back so that it can be reacted upon (React).

These micro-level processes also resonate with the comment by Scott *et al.* (2004) in response to a model by Wang (2003):

> In this model the seemingly endless number of possible ways of describing the application of e-health has been reduced ... to the collection, analysis, and transfer of data and information.

5.3.3.2 Simplifying the number of micro-level processes

No changes were made to the telemedicine service dimension from the second to the third iterations of the TMSMM (Figure 5.3). However, two significant change were made during the fourth iteration. The first change, as explained in the previous paragraphs, involved the addition of a meso- and macrolevel layer.

Secondly, in the final conceptual model, the microlevel telemedicine service was simplified: The second and third iterations of the microlevel telemedicine service (then named telemedicine process) included nine steps, as opposed to the four steps of the final TMSMM. This simplification came about as a consequence of the development of the domain dimension. As will become clearer in the next section, a fifth domain was added as part of the final iteration of the TMSMM conceptual model. This fifth domain was created to include the material of the telemdicine service, namely information.

All steps that were removed from the telemedicine service (refer to *italics* in Figure 5.3) related to data/information (material). These steps were initially included to incorporate issues such as data security, syntactic and semantic interoperability, retention of data quality after compression and record keeping. In the final version of the TMSMM these issues were addressed by the material domain, which included all issues related to data and information.

5.4 Combining the Domain Dimension with the Service Dimension

Figure 5.4 shows the matrix that is formed by the domain dimension (vertical axis) and the *Service* dimension (horizontal axis). The areas that are formed as consequence are labeled in the orange cells.

For purposes of this study these areas (represented by the orange cells) are referred to as capability areas and defined as clusters of related activities, associated with a specific combination of dimensions, spanning over all maturity levels. De Bruin *et al.* (2005) explains that capability areas provide further detail enabling targeted maturity level.

The micro-level processes in combination the domains, form a framework according to which any telemedicine service can be described, hence addressing the first design requirement. A few examples of these are described in Appendix D includes two case studies, which are described in detail, namely a teleradiology service within the private health sector of South Africa (Section D.1.2) and a pilot project of a teleophthalmology service (Section D.1.1). For each of these services a dashboard in shown in the respective sections, according to which these telemedicine services are described and assessed. The design of this dashboard is based on Figure 5.4.

Design Requirement 1: The TMSMM can describe any healthcare service that is delivered over a distance.

	Micro-Level Telemedicine Processes		Higher Level Telemedicine Processes	
	Capture, Diagnose/ Analyze, React processes	Data Transmission processes	Meso-level processes	Macro-level processes
Man	patient or healthcare worker	patient or healthcare worker	healthcare worker community	society
Machine	telemedicine device/ mobile phone/ app etc.	internet service, mobile phone network etc.	physical infrastructure	interorganizational system
Material	data	data/ images/ video ect.	electronic medical records (EMRs)	electronic health records (EHRs)
Method	work procedure	network service	change management process	policies and strategies
Money	operational costs	cost of transmission service	interorganizational business model	national business case

Figure 5.4: A matrix according to which a telemedicine service can be described

5.5 Maturity Scale

A maturity scale is a design component of any maturity model and it relates to four of the design requirements for the TMSMM:

Design Requirement 2: The TMSMM enables the assessment of the maturity of a telemedicine service.

Design Requirement 4: The TMSMM can be used as basis for education and explaining standards.

Design Requirement 11: The capability statements and maturity level accumulates. Each higher level statement also includes the preceding lower level statements.

Design Requirement 12: Descriptions of capability statements clearly relate to and discriminate between maturity levels.

This maturity scale provides a yardstick according the which the telemedicine service can be described (DR 2) and because of its cumulative (DR 11) nature, also provide guidance towards a more mature state (DR 4). DRs 11 and 12 are partially addressed by the maturity scale, but are revisited in Chapter 6 when the formulation of the capability statements are described.

The domain dimension, as well as the service dimension, has developed significantly since the first iteration. In contrast, the *Maturity Scale* underwent only minor changes (refer to Figure 5.5).

Iteration 1	Iteration 2	Iteration 3	Iteration 4
ISO/IEC 15504	**Combination of CMM and NIMM**	**Based on CMM**	**Based on CMM**
0. Incomplete			
1. Performed	1. Initial, ad hoc, basic	1. Initial	1. Ad hoc
2. Managed	2. Managed, stable, controlled	2. Managed	2. Managed
3. Established	3. Defined, standard	3. Defined	3. Standard
4. Predictable	4. Measured, optimised	4. Measured	4. Measured
5. Optimising	5. Optimising, Innovative, strategic	5. Optimised	5. Optimising

Figure 5.5: The development of the maturity scale dimension

5.5.1 First iteration

For the first iteration, the ISO/IEC 15504 maturity scale was used. The reason for this was that this scale is often used in conjunction with the ISO/IEC 15288 Systems Engineering Life Cycle. Due to the fact that the latter was not included in the second and third iterations, the reason for including the ISO/IEC 15504 maturity scale became irrelevant.

5.5.2 Second, third and fourth iteration

The maturity scale of the TMSMM is based on the generic level indicators of the capability maturity model (CMM). This is done for four reasons:

First, most of the existing maturity models use a maturity scale, which is either identical to, or strongly resembles the CMM-scale. This is indicative of the generic usefulness and validity of this scale.

Secondly, it opens up the possibility that the TMSMM can be used in conjunction with comparative CMM-like maturity models, for example those developed for project management (Kerzner, 2002), and knowledge management (Kochikar, 2000).

Thirdly, in Design Requirement 6, it is acknowledged that for the TMSMM, the main concern is *process* maturity, as is the case for the CMM. The maturity levels are defined from this viewpoint.

Finally, many of the telemedicine frameworks presented in Chapter 4 emphasize the importance of evidence and the need for the systematic monitoring and evaluation of telemedicine services. The CMM maturity scale is based on a process control principle, where a process is first standardized (maturity level 3) and then quantitatively measured (maturity level 4), before it can be optimized. By using this scale, which include quantitative management, the TMSMM ensures that monitoring and evaluation are considered for all domains and all types of processes.

The maturity levels used for the purposes of the TMSMM, as derived from the CMMI maturity levels, are described below:

1. **Initial (chaotic, ad hoc):** The starting point for use of a new or undocumented repeat process.
2. **Repeatable:** The process is at least documented sufficiently so that repeating the same steps can be attempted.
3. **Standard:** The process is defined/confirmed as a standard business process.
4. **Quantitatively Managed:** The process is quantitatively managed in accordance with agreed-upon metrics.
5. **Optimizing:** Process management includes deliberate process optimization/ improvement.

A **Level 0**, namely *incomplete process* is also included in the TMSMM, similar to some CMMs. Level 0 accommodates capabilities statements that imply that no capability whatsoever, exists. Although level 0 capability statements are included, level 0 is not included as a maturity level. In doing so, the CMM practice is followed.

5.5.3 Domain-specific maturity scale

A total of ten domain-specific maturity scales are defined. These scales combine the domain dimension and maturity scale. The descriptions of these scales are themes that were taken from the state of the art, the stakeholder workshops and well as case studies based on earlier versions of the TMSMM. These domain-specific scales evolved together with the *Domain* dimension.

A maturity scale is developed for each component of the domain dimension (man, machine, material, method and money) related to microlevel services (Figure 5.6). Similarly, five domain-specific maturity scales are defined for the higher level processes (Figure 5.7). In the next chapter, the capability statements are defined along these domain-specific maturity scales.

Micro-level Telemedicine Service		Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
		no	initial	repeatable	defined	quantitatively managed	optimizing
man	patient or healthcare worker	no-one	entrepreneur	champion	standard	performance management	professional development
machine	telemedicine device/ mobile phone/ app etc.	nothing	experiment	pilot	standards and inter-operability	monitored	maintenance and upgrades
material	data	no data	uncertain quality	consistent quality	quality standards	quality control	quality improvement
method	work procedure	no innovation	ad hoc	effective	work standards	performance control	continuous improvement
money	operational costs	no funds	R&D / entrepeneur	consistent, but temporary	consistent and permanent	accountability	cost optimization

Figure 5.6: Five domain-specific maturity scales for microlevel processes

Meso- and Macro Level Telemedicine Processes		Level 1	Level 1	Level 2	Level 3	Level 4	Level 5
		ad hoc	initial	repeatable	defined	quantitatively managed	optimizing
man	community	no community	resistance / ignorance	acceptance	norm	evidence	change to community
machine	infrastructure	none	insufficient	managed	standards and inter-operability	monitored	continuous improvement
material	record management	no records	temporary	isolated	integrated	business intelligence	business optimization
method	change management	not existing	experiment	bottom-up	top-down	performance and health indicators	continuous improvement
money	business models	research	fragmented	synergy	sustainable	health economics	value optimzation

Figure 5.7: Five domain-specific maturity scale for meso- and macrolevel processes

5.6 Conclusion

This chapter, together with the next two chapters, addresses the fifth objective of this study, namely to develop a new telemedicine service maturity model (TMSMM). In order to approach the design of the conceptual model in a scientific way, the state of the art was described in Section 3.5 to arrive at a top-down iterative design approach. The first phase of the top-down approach is to develop a conceptual model, which was the focus of this chapter.

The following components of the conceptual TMSMM were described in the chapter:

- The domain dimension (Section 5.2).
- The service dimension (Section 5.3).
- A matrix, which is formed by these two dimensions and according to which a telemedicine service can be described (Figure 5.4). Each cells of this matrix each represents a capability area.
- A maturity scale (Section 5.5)
- Domain-specific maturity scales, again in the format of two-dimensional matrices (figures 5.7 and 5.6).

When all these components are combined, a three-dimensional conceptual model is created, as shown in Figure 5.8. For each of the capability areas a set of capability statements is defined along the maturity scale, as indicated in Figure 5.9.

Research Question 5.1: What conceptual design will address the design requirements?

This conceptual model addresses DR 1 (Section 5.3) as well as DRs 1, 2, 4, 11 and 12 (Section 5.5). The conceptual model is designed in such a way that it can accommodate the formulation of capability statements (Chapter 6), followed by the development of the assessment methodology (Chapter 7). The other design requirements are addressed in these chapters. The definition of the capability statements, within the context of this conceptual model is described in the next chapter.

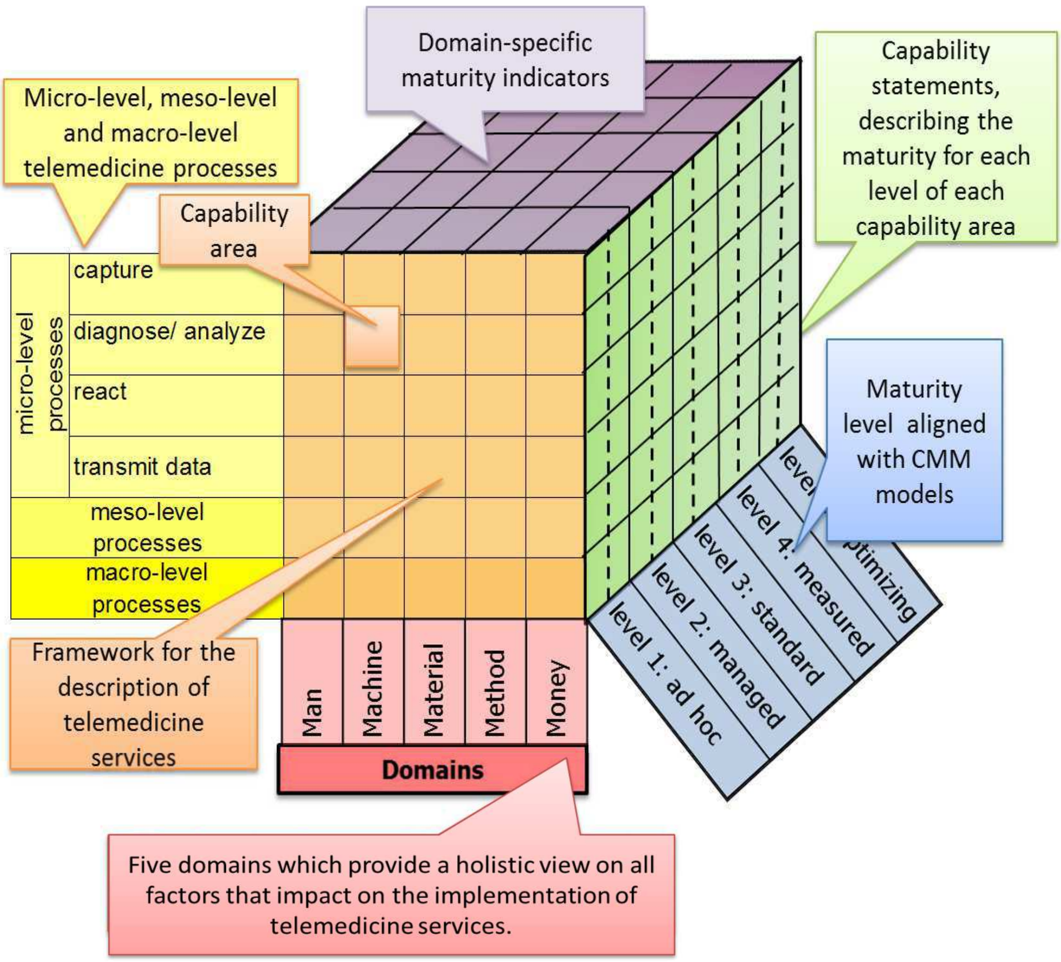

Figure 5.8: The conceptual model

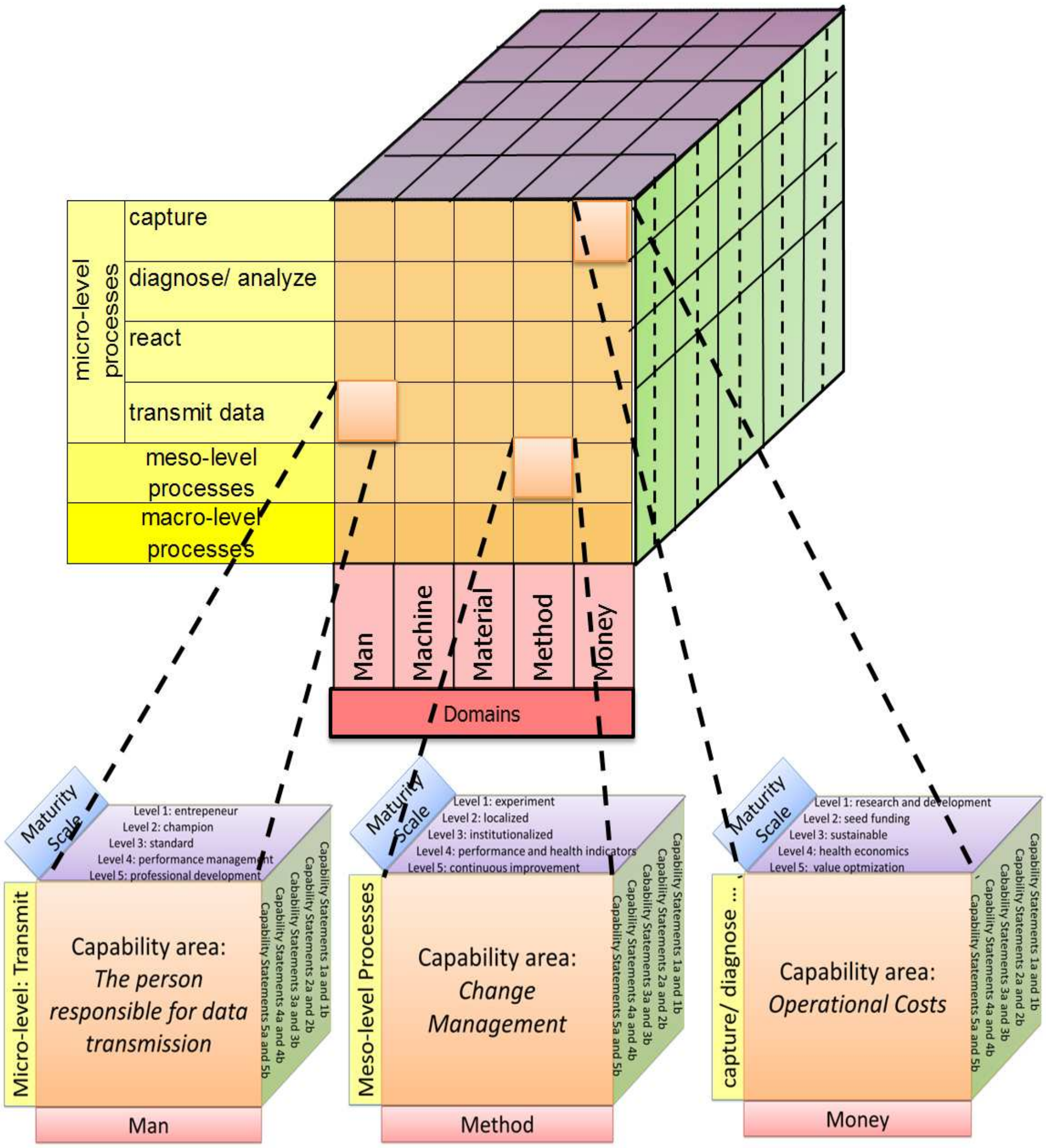

Figure 5.9: Examples of sets of capability statements for each capability area

Chapter 6

Development of Capability Statements

Chapters 5, 6 and 7 describe the telemedicine service maturity model (TMSMM) and the iterative design approach that was followed to develop this model (Figure 6.1). A top-down development approach (De Bruin *et al.*, 2005) is followed, which means the conceptual TMSMM is developed first in Chapter 5, after which the capability statements are formulated for each capability area.

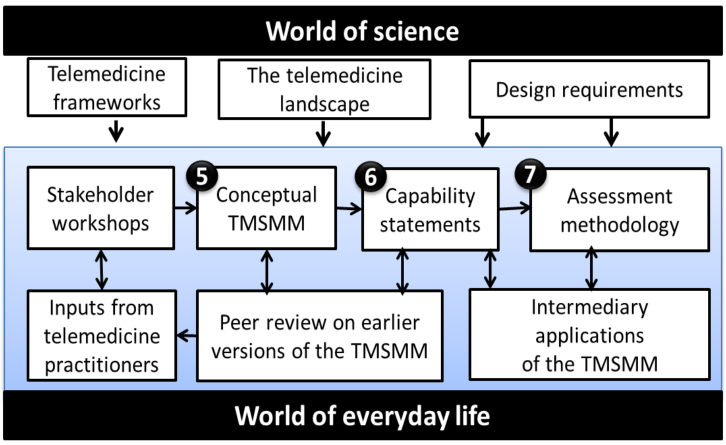

Figure 6.1: Research roadmap: Development of the TMSMM

A capability statement is a generic statement that describes a characteristic of a process as it applies to a specific maturity level. A scale is an instrument by means of which a quantitative value can be associated with an intangible concept. For example, weight is measured by a weighing scale in units of *grams*. Similarly, the set of capability statements provides a scale to allocate a quantitative value to an intangible concept, such as maturity. The unit of measurement is the maturity level.

Many maturity models do not include capability statements. However, concepts such as *improvement measures*, *criteria* (De Bruin *et al.*, 2005; Mettler, 2011), *common features*, *key practices* and *goals within a process area* (Paulk *et al.*, 1993; Bate *et al.*, 1995) serve more or less the same purpose. In this chapter the capability statements for each capability area of the conceptual TMSMM are presented. The significance and appropriateness of these statements are supported with evidence from the state of the art. The following research question applies:

Research Question 5.2: How should the capability statements be formulated to address the design requirements?

6.1 Iterative Design Process

Figure 6.1 indicates not only this chapter's position in the iterative design process; it also shows the inputs to the development of the capability statements, namely (1) the design requirements, (2) intermediary applications of the TMSMM, (3) existing frameworks and insights from the state of the art, and (4) the conceptual TMSMM. Each of these inputs is elaborated upon in the section that follows:

6.1.1 Design requirements

The last four design requirements were defined in Section 3.6.5, based on design considerations concerning maturation paths and capability statements. These design requirements (DRs) served as controls in the process of defining capability statements:

Design Requirement 8: The TMSMM is not directly tied to any standards, technologies or concrete implementation details.

Design Requirement 9: The capability statements are mutually exclusive.

Design Requirement 10: The capability statements are collectively exhaustive.

Design Requirement 11: Descriptions of capability statements clearly relate to and discriminate between maturity levels.

Design Requirement 12: The capability statements and maturity levels accumulate. Each higher level statement also includes the preceding lower level statements.

6.1.2 Inputs from the world of science

Throughout this chapter, it is explained how insights from the state of the art contributed to the formulation of the capability statements.

6.1.3 Inputs from the world of everyday life

Earlier versions of the TMSMM were applied to a variety of telemedicine services as part of other studies. Some of these studies are published (Van Dyk *et al.*, 2012*b*; Van Zyl, 2012; Viljoen, In process; Triegaardt, 2013). These studies provided input from the world of everyday life towards the definition of capability statements.

6.1.4 The conceptual TMSMM

The conceptual TMSMM consists of 30 capability areas (5 domains for 6 process types). Each of these capability areas is represented by one block in Figure 5.9. The iterative design process that was followed to progress from the conceptual model to the formulation of the capability statements is shown in Figure 6.2.

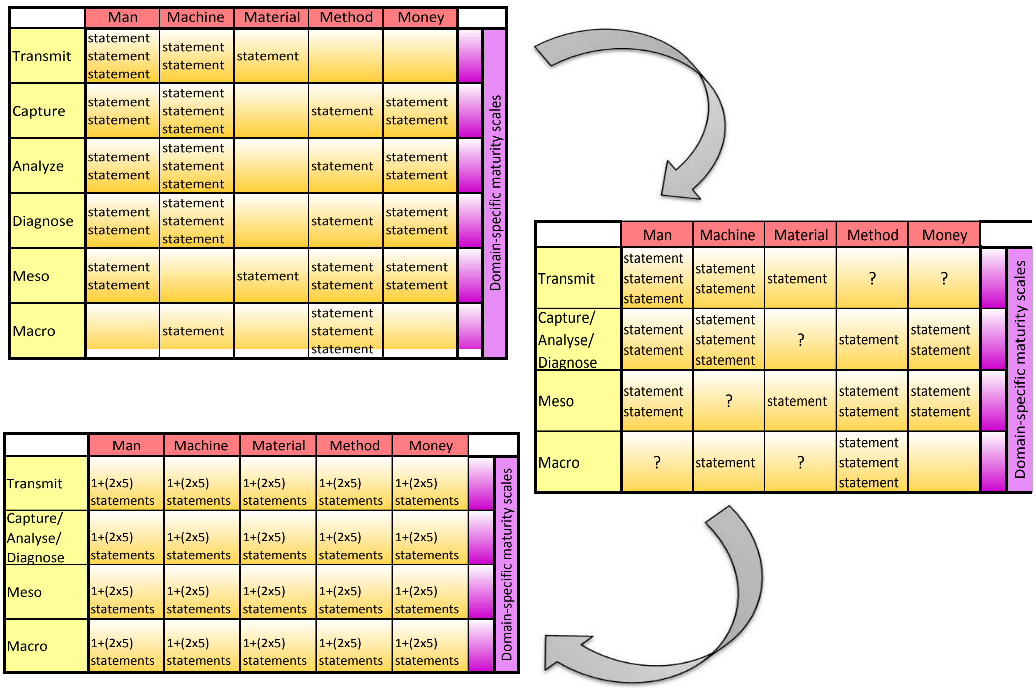

Figure 6.2: Iterative design process to develop capability statements

For the first iteration inputs from the world of science and world of everyday life contributed to the definition of generic statements that describe characteristics of a process. These statements were positioned on the conceptual model along the domain-specific maturity scales. During this first iteration, some modifications were also made to the domain-specific maturity scale as part of the design of the conceptual model.

It was also during earlier iterations that it became clear that the microlevel processes *capture*, *diagnose*, *analyze* and *react* involve the same type of human resources, devices, applications, electronic records, operational procedures and costs.

For this reason they were grouped together and share the same set of capability statements, as indicated in Figure 5.9.

A next iteration was executed, specifically focussing on less populated capability areas, again drawing from the world of science and the world of everyday life generic statements that describe characteristics of a process as they apply to a specific maturity level.

Initially there was not a particular number of capability statements per capability area. After a few iterations it became evident that in many cases two capability statements are defined per maturity level per capability area. This finding also resonates with the observation concerning the PACS maturity model which states "based on our rigorous approach, we believe that two [capability statements] are optimal from both a scientific and practical perspective. In addition, the experts were convinced this would cover sufficient amounts of detail" (Van de Wetering, 2009).

It was decided to pursue this as a design principle. Hence, further iterations were focussed on defining exactly two capability statements per maturity level per capability area, together with the single level 0 capability statement. It is shown in the next chapter how this design principle contributes to the satisfaction of DR 5 and DR 7. This design principle also resonates with DR 11.

Design Requirement 5: The maturity assessment methodology can be followed easily and intuitively.

Design Requirement 7: Results from a cohort of individual service assessments can be aggregated along all dimensions to an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic level decision-makers.

Design Requirement 11: Descriptions of capability statements clearly relate to and discriminate between maturity levels.

The end result of this iterative design process is presented in the remainder of this chapter. The five sections that follow focus respectively on the capability areas of each of the five domains. For each capability area a total of 11 capability statements are presented and discussed: two statements for each of the five maturity levels and one statement prior to maturity level 1.

6.2 Capability Statements for the *Man* Domain

For the *Man* domain, the capability statements are identical for all microlevel processes, namely capture, diagnose, react and transmission processes (Table 6.1).

6.2.1 Users of telemedicine services

Table 6.1: Capability area: Individual user

Level	**Maturity scale**	**Capability statements**
Level 0	no-one	The patient or healthcare worker is not available.
Level 1a	entreperneur	The patient or healthcare worker is available, but not always at the appropriate time.
Level 1b	entreperneur	The patient or healthcare worker is normally available at the appropriate time
Level 2a	champion	The patient or healthcare worker wants to execute this process.
Level 2b	champion	The patient or healthcare worker executes this process consistently.
Level 3a	standard	The patient or healthcare worker is trained to exectue this telemedicine process as standard procedure.
Level 3b	standard	The patient or healthcare worker has the mandate to execute the telemedicine process as standard procedure.
Level 4a	performance management	The patient or healthcare worker is measured when and how he does this.
Level 4b	performance management	The patient or healthcare worker is monitored and appraised when and how he does this.
Level 5a	professional development	The patient or healthcare worker performance is continously improved through the execution of this service.
Level 5b	professional development	The patient or healthcare worker contributes to the training and development of peers towards doing this.

Telemedicine services have a wide range of users. Depending on how the service is set up, the telemedicine process can include patients, as well as healthcare workers such as medical specialists, nurses, radiologists, midwives, primary care practitioners and counsellors.

Patients are not always the users of the system (Rudel *et al.*, 2011). For example, a nurse can use a telemedicine service to deliver appropriate care to a patient. In this case, the nurse is considered to be the user of the telemedicine service and not the patient. By the same token, the role of ICT technologist is imperative for the operation of a telemedicine service, but the ICT technologist is not necessarily a user of the system.

Initially users are not necessarily qualified and mandated to participate in the telemedicine service (level 1). A champion (level 2) is a user from the community who takes on the role of innovator and advocate. Many authors, for example Araki *et al.* (2007), Wade and Eliott (2012), Mars (2009) and Yellowlees (2005) list the involvement of a so-called champion as a critical success factor in the successful implementation of telemedicine services. It is typically, but not necessarily, the champion who wants to execute this process and who does so consistently, before standards are set (level 2).

The service is standard (level 3) in terms of this capability area if processes are in place to ensure that every user of that process, now and in future, is trained and mandated to execute the task consistently as standard and on an ongoing basis.

Another determinant for the successful implementation of telemedicine is the integration of the telemedicine service with other business processes of the hospital or healthcare system (Broens *et al.*, 2007; Yellowlees, 2005; Khoja *et al.*, 2013*a*). For example, when the users are human resources of the hospital or healthcare system, integration with the human resource business process is expected. This capability area is quantitatively managed if user performance metrics exist for each of the steps of the telemedicine process and if the user performance is appraised accordingly (level 4).

Even though the patient is not an employee of the telemedicine service, it is important that some procedures exist to measure and reward the treatment adherence of the patient. The target maturity state (level 5) concerns the continuous professional development of the user (in the case of healthcare workers) or empowerment (in the case of the patient). Procedures are in place to ensure that through training, education, mentorship or peer support, the user can improve his or her performance. The user also contributes to the development of others.

6.2.2 Communities

> As each individual piece is placed in the community puzzle, a new whole is created. This new whole is able to overcome former obstacles blocking individuals. As a result, community issues may not directly reflect individual interest; however, such issues will directly affect each individual within the community (Hicks *et al.*, 2004)

Telemedicine services inevitably cut across epistemic communities, for example medical practitioners, technicians, patients or public health practitioners (Schrapel, 2010). The users of each step of the telemedicine process are members of one of these communities.

On a microlevel the *Man* domain is described as the individual user of the technology that captures, diagnoses, reacts or transmits data. The *healthcare worker community* (Table 6.2) and the patient community, thus *society* (Table 6.3), are added as mesolevel and macrolevel capability areas respectively.

Table 6.2: Capability area: Healthcare worker community

Level	Maturity scale	Capability statements
Level 0	no community	The healthcare worker community is not aware of this service.
Level 1a	resistance / ignorance	The healthcare worker community resists this service.
Level 1b	resistance / ignorance	The healthcare worker community avoids this service.
Level 2a	acceptance	The healthcare worker community's perception is that this service is easy to use.
Level 2b	acceptance	The healthcare worker community's perception is that this service will contribute to job performance.
Level 3a	norm	The healthcare worker community's organizational considers the service mandatory.
Level 3b	norm	The healthcare worker community's organizational culture strengthens the use of this service.
Level 4a	evidence	The healthcare worker community's adoption of the service is measured.
Level 4b	evidence	The healthcare worker community's adoption of the service is measured by means of evidence-based scientific study.
Level 5a	change to community	The service contributes to the professional development and positive task shift of the users.
Level 5b	change to community	Continuous capacity building of the healthcare worker community takes place.

Table 6.3: Capability area: Society

Level	Maturity scale	Capability statements
Level 0	no community	The society is not aware of this service.
Level 1a	resistance/ ignorance	The society may be aware, but is not deliberately made aware of this service.
Level 1b	resistance/ ignorance	Society is deliberately made aware of this service.
Level 2a	acceptance	Society is willing to receive this service.
Level 2b	acceptance	Society wants to receive this service.
Level 3a	norm	A sufficiently large portion of the society already used this service for most issues to be addressed.
Level 3b	norm	Society considers this telemedicine service as the norm.
Level 4a	evidence	The impact on society is known and monitored.
Level 4b	evidence	The impact on society is scientifically quantified.
Level 5a	evidence	The service is continuously improved and scaled up to increase the benefit to society.
Level 5b	evidence	Other similar societies can learn from the example of this service.

6.2.3 Technology acceptance amongst healthcare workers

The skills, aptitude and attitude of the individual user does not necessarily reflect the skills, aptitude and attitude of the community to which he or she belongs. The individual users of telemedicine services are often innovators and early adopters (Rogers, 1995), which is not the norm for the population. The mesolevel of the *Man* domain concerns the typical healthcare worker.

In Section 4.3.2 the UTAUT was presented as one of the frameworks that is used to measure and manage an aspect of telemedicine implementation. Capability statements 2a (perceived ease of use), 2b (performance expectancy), 3a (voluntariness) and 3b (social influence) are derived from the UTAUT. Capability statement 3b also aligns with the observation by Leon *et al.* (2012) that for telemedicine services to be successful, they must be embedded in the culture of an organization. Khoja *et al.* (2013*a*) also points out that cultural acceptability to society is critical to the success of the telemedicine service.

6.2.4 Continuous education and professional development

Continuous education and the professional development of healthcare workers are captured by the last four capability statements of this capability area (Table 6.2).

Telemedicine services provide the opportunity for continuing clinical education, especially of primary healthcare providers in rural resource-constrained areas. According to Lustig (2012), it is important that skills with regard to the use of telemedicine services are included in the formal training of healthcare workers. Examples of such services are provided by Colven *et al.* (2011) (dermatology), Uys and Van Dyk (2011) (tele-ultrasound), Wynchank and Fortuin (2011) (telenursing) as well as Hazin and Qaddoumi (2010) (teleoncology).

What Finch *et al.* (2006) call *professional boundary crossing* is labelled *task-shifting* by the World Health Organization (Bhutta *et al.*, 2010). Task shifting entails the reallocation of certain tasks from more specialized to less specialized health care workers across the board. For example, tasks are shifted from the physician to non-professional health care workers (Hermann *et al.*, 2009; Fulton *et al.*, 2011).

An example of task shifting is the case of community health workers (CHWs) being recruited from semi-skilled communities and trained to perform often routine tasks, previously performed by highly educated physicians, such as HIV or diabetes screening (Bhutta *et al.*, 2010). As a result, physicians would have more time to focus on more specialized procedures, and a much needed opportunity for job creation would be provided. A maturity level of 5 is allocated on Table 6.2 if the telemedicine service deliberately causes task shifts for an entire professional community.

6.2.5 Evidence-based practice

Kidholm *et al.* (2012) make it clear that MAST can only be used to assess the outcomes of a telemedicine service once a sufficiently large portion of a society is using this service for most issues to be addressed. Similarly in the maturity scale of the TMSMM - as adopted from the CMMs – standardization (level 3) – precedes quantitative management (level 4). The maturity level 3 capability statements are defined accordingly (Table 6.3).

Evidence-based practice is an interdisciplinary approach that originates from evidence-based medicine and has spread to other fields over the past two decades. Evidence-based medicine strives for the ideal that healthcare professionals should make "conscientious, explicit, and judicious use of current best evidence in everyday practice" (Sackett *et al.*, 1996). In light of this, it is likely that healthcare workers and other professionals are familiar with this concept.

Evidence-based practice dictates, first, that all practical decisions should be based on research studies and, secondly, that these research studies should be selected and interpreted according to a specific and quantitative norm. If scientifically acceptable and practically useful quantitative measures of the impact on the user community is quantified, then capability statement 4b applies.

Despite the challenges in executing scientifically rigorous evidence-based studies, Finch *et al.* (2006) found that evidence concerning the effectiveness of teledermatology services was one of the six factors detrimental to the adoption thereof. The teledermatology services that became normalized were those for which the perceived benefits clearly outweighed the effort and commitment required to make the system work. Capability statement 4a (Table 6.2) indicates that the impact on the community of healthcare workers is known and monitored, even though it may not be by means of a scientific evidence-based study.

6.3 Capability Statements for the *Machine* Domain

This domain concerns technology and infrastructure. On microlevel, the same set of capability statements are used for devices and applications that capture, diagnose, analyze and react. The same capability statements apply to hardware (devices) and software (applications). A second set of microlevel capability statements is defined with respect to the network service (internet network/ mobile service etc.). The mesolevel "machine" involves the physical infrastructure and is not limited to information technology only.

6.3.1 Telemedicine devices and applications

Table 6.4 applies to the devices and applications that relate to the microlevel processes of capture, diagnose and react. Broens *et al.* (2007) explain that during the experimental phase (level 1) the focus is on technological feasibility. Taylor (2005) adds that during the experimental phase, the safety of a telemedicine device must first be established before the service can be piloted. Safety is also one of the seven domains of the MAST.

Table 6.4: Capability area: Telemedicine device or application

Level	Maturity scale	Capability statements
Level 0	nothing	The telemedicine device/mobile phone/app etc. never existed.
Level 1a	experiment	The telemedicine device/mobile phone/ app etc. is confirmed to be safe.
Level 1b	experiment	The telemedicine device/ mobile phone/ app etc. is used on an ad hoc/ experimental basis.
Level 2a	pilot	The telemedicine device/mobile phone/app etc. is effective and available, but still undergoes frequent modifications.
Level 2b	pilot	The telemedicine device/mobile phone/app etc. is effective, reliable and available.
Level 3a	standards and interoperability	The telemedicine device/mobile phone/app etc. is interoperating with upstream and downstream devices and applications.
Level 3b	standards and interoperability	The telemedicine device/mobile phone/app etc. is operating according to a defined standard.
Level 4a	monitored	The telemedicine device/mobile phone/app's availability is monitored.
Level 4b	monitored	The telemedicine device/mobile phone/app 's availability, reliability and maintainability are monitored.
Level 5a	maintenance and upgrades	The telemedicine device/mobile phone/app's corrective maintenance is executed effectively and timely.
Level 5b	maintenance and upgrades	The telemedicine device/mobile phone/app's preventative maintenance and upgrades are executed effectively and timely.

During the pilot phase (level 2) the device is effective and available, but still undergoes frequent modifications (Drummond *et al.*, 2008). For a repeatable telemedicine service the telemedicine device and/or software must be regularly available and maintained. User support must be available within the context in which the device and/or software is to be used, although it is not necessarily standard practice. This is typically what happens with pilot projects.

Interoperability is the ability of diverse systems and organizations to work together, i.e. to interoperate. Interoperability ensures there is smooth communication across technological and information devices and platforms (Leon *et al.*, 2012). Many of the telemedicine systems in use today are adaptations or reconfigurations of existing technology, for example teleconferencing, desktop computer systems or mobile phone technology (McCaffery and Dorfling, 2010). A lack of technical, semantic and syntactic interoperability often results in these services not being sustained. To accomplish a maturity level of 3 (defined), the device and the way in which it interoperates with upstream and downstream devices must be defined as standard. The TMSMM itself does not prescribe the specific technology and standards.

Interoperability standards accross a service and across organizational units is considered as part of the macrolevel capability area, *Interorganizational system* in Table 6.7. Leon *et al.* (2012) explain that uniform standards are required for interoperable systems and are developed through consensus among multiple of stakeholders.

The quantitative management of telemedicine devices and applications (level 4) should be directed to availability (system is operating satisfactorily at any time), reliability (system will perform its intended function satisfactorily) as well as maintainability (the ease and rapidity with which a system or equipment can be restored to operational status following a failure (Parker, 1984)). In the target maturity state (level 5) corrective as well as preventative maintenance is executed effectively and timely.

6.3.2 Network service

Each telemedicine process has at least two transmission processes. For example, it is possible for a patient to transmit an image of his skin via MMS-service from a public mobile phone service provider to a dermatologist. The dermatologist can then respond by submitting feedback via a conventional telephone line or possibly a wireless LAN. As in the example, the respective transmission processes use different transmission networks. Each of the transmission processes on microlevel is defined and assessed separately, according the capability statements shown in Table 6.5.

The network service can be delivered internally (for example via company intranet). However, in the case of telemedicine services, external service providers, for example mobile phone operators, are most often used. Within the context of the public health sector of South Africa the State Information Technology Agencies (SITA) provides the internet service between public health care facilities.

Table 6.5: Capability area: Transmission network

Level	Maturity scale	Capability statements
Level 0	nothing	The internet service, mobile phone network etc. never existed.
Level 1a	experiment	The internet service, mobile phone network, etc. is not available anymore.
Level 1b	experiment	The internet service, mobile phone network, etc. is confirmed to be available.
Level 2a	pilot	The internet service, mobile phone network, etc. transmits data effectely.
Level 2b	pilot	The internet service, mobile phone network, etc. transmits data effectely at an acceptable speed.
Level 3a	standards and interoperability	The capacity (bandwidth) of internet service, mobile phone network, etc. was considered in the design of the service.
Level 3b	standards and interoperability	The interoperability of the internet service, mobile phone network, etc. is considered in the system's standards design.
Level 4a	monitored	The reliability and availability of the internet service, mobile phone network, etc. can be measured.
Level 4b	monitored	The reliability and availability of the internet service, mobile phone network, etc. are monitored.
Level 5a	maintenance and upgrades	Deviations from acceptable levels of availability and reliability is continuously addressed.
Level 5b	maintenance and upgrades	The capability, reliability and availability of the internet service, mobile phone network, etc. are continuously improved.

During the research phases (levels 1 and 2) the network service is mostly developed without the involvement of a service provider. The service is assumed to be available. At standard service level, standard service level agreements with the service provider are required (level 3). A maturity level of 4 indicates that adherence to these service level agreements is continuously monitored. To attain a maturity level of 5, the service providers ensure that these agreements are continuously and appropriately upgraded and upscaled.

6.3.3 Physical infrastructure

> Clinicians are generally busy people who will regularly use a service, or an instrument, only if it is immediately accessible. Walking across the road is sometimes too far to go ... Read user-friendliness means that a clinician has a video-conferencing facility in the normal workplace, or that a teacher can give a lecture in the usual seminar room (Yellowlees, 1997).

The *Machine* domain does not only involve ICT. The different devices and applications are all subsystems, which fit into a larger physical infrastructure. As explained in Chapter 2, *telemedicine* is often defined within the context of its intended use, for example home-based care or the delivery of healthcare to rural areas. In either case, the capability of the physical environment is crucial to the success of the telemedicine service.

For example, as part of the implementation protocol of a home-based telemedicine service, the suitability of the home environment to facilitate the telemedicine service should be considered. Within the context of rural healthcare, the service can be delivered from or to a mobile clinic vehicle or from a rural primary care clinic at a local school.

The maturity of the physical infrastructure (refer to Table 6.6) depends on its appropriateness (level 1) availability (level 2). Level 3 always indicates that standards are set. A maturity level of 4 indicates that the availability, reliability and maintainability is monitored. The target maturity state is one were the infrastructure is continuously maintained as well as upgraded and upscaled when needed.

Table 6.6: Capability area: Physical infrastructure

Level	**Maturity scale**	**Capability statements**
Level 0	none	The physical infrastructure never existed.
Level 1a	insufficient	The physical infrastructure is neither appropriate nor available.
Level 1b	insufficient	The physical infrastructure is either not appropriate or not available.
Level 2a	managed	The physical infrastructure is appropriate and mostly available.
Level 2b	managed	The physical infrastructure is appropriate and always available.
Level 3a	standard	The physical infrastructure is set up specifically for this service according to defined design standards.
Level 3b	standard	The physical infrastructure is set up specifically for this service according to defined design standards.
Level 4a	monitored	The availability of the physical infrastructure is monitored.
Level 4b	monitored	The physical infrastructure'availability, reliability and maintainability are monitored.
Level 5a	continuous improvement	The physical infrastructure is continuously maintained and upgraded whenever needed.
Level 5b	continuous improvement	The physical infrastructure is scalable (can easily be expanded to accommodate more instances of this service).

6.3.4 Interorganizational system

> Interorganizational relationships did exist in health care long before tele-cooperation. A common example is the cooperation between primary care [facilities] and hospitals. The technology is the basis for a new form of network organization, i.e. the technology allows closer collaboration between geographically dispersed organizations (Aas, 2007).

The first capability statements shown in Table 6.7 are based on the work of Aas (2007). The synchronization of resources (levels 1 and 2) are key to an effective interorganizational system. As explained in Section 6.4, interoperability standards accross the interorganizational system indicate a maturity level of 3 for this capability areas. The performance of the interorganizational system is typically monitored by key performance indicators (level 4). The target maturity state is one where the organization is adopted to fit the need, as recommended by Aas (2007) (level 5).

Table 6.7: Capability area: Interorganizational system

Level	**Maturity scale**	**Capability statements**
Level 0	none	The inter-organizational system never included the telemedicine service.
Level 1a	insufficient	The interorganizational system can not accommodate the telemedicine service.
Level 1b	insufficient	The interorganizational system's technology and resources are not synchronized.
Level 2a	managed	The interorganizational system's technology and resources are sometimes synchronized.
Level 2b	managed	The interorganizational system's technology and resources are mostly synchronized.
Level 3a	virtual organization	The interorganizational system's interoperability standards are defined.
Level 3b	virtual organization	The interorganizational system's interoperability standards are followed throughout the system.
Level 4a	monitored	KPIs are defined with the new organizational design in mind.
Level 4b	monitored	KPIs are routinely measured and reported on.
Level 5a	continuous improvement	The interorganizational system is continuously adopted to fit the need.
Level 5b	continuous improvement	The interorganizational system is scalable (can easily be expanded to accommodate more instances of this service).

6.4 Capability Statements for the *Material* Domain

A telemedicine service converts raw data into useful information, similar to any manufacturing process in which raw material is converted into a useful product.

6.4.1 Data

The capability statements shown in Table 6.8 apply the data in the telemedicine context (e.g. text, static images or video stream), which result from the capture, diagnose or react process. Many factors influence the quality of data, and specifically images, that are used as part of the telemedicine process. The TMSMM does not define any quality standards. Rather, this capability area involves the **process** of controlling that quality.

The principles of process control, which are inherent to the maturity levels of the family of capability maturity models (CMMs), also apply here. It is possible for a telemedicine service to be effective, without any predefined quality standards (maturity level 2). Once quality standards are set (maturity level 3), this quality can be measured and monitored (level 4), so that causes of unacceptable quality can continuously be identified and addressed (level 5).

Table 6.8: Capability area: Used data

Level	**Maturity scale**	**Capability statements**
Level 0	no data	The data do not exist.
Level 1a	uncertain quality	The data are of varying and most often unacceptable quality.
Level 1b	uncertain quality	The data are of varying but most often acceptable quality.
Level 2a	consistent quality	The data are created consistently at a mostly acceptable quality.
Level 2b	consistent quality	The data are created consistently, always at an acceptable quality.
Level 3a	quality standards	The physical quality standards of the data are defined within context of this service.
Level 3b	quality standards	The clinical effectiveness of the data are defined.
Level 4a	quality control	The physical quality of the data are measured.
Level 4b	quality control	The effectiveness measures for the physical quality of the data are effectively reported.
Level 5a	quality improvement	Causes of unacceptable quality are continuously identified.
Level 5b	quality improvement	Causes of unacceptable quality are continuously and effectively addressed.

6.4.2 Data transmission processes

Many studies consider the effect of (the lack of) bandwidth on the quality of telemedicine data and images, together with strategies to retain quality. The control of the quality of images is considered in the previous capability area. The capability statements of the data transmission process (Table 6.9) indicate the capability to transmit the data securely and consistently.

Table 6.9: Capability area: Transmitted data

Level	**Maturity scale**	**Capability statements**
Level 0	no data	The data/ images/ video etc. do not exist.
Level 1a	uncertain quality	The data/images/videos etc. sometimes get lost.
Level 1b	uncertain quality	The data/images/videos etc. do not get lost.
Level 2a	consistent quality	The ddata/images/videos etc. can easily be viewed by an unauthorized person.
Level 2b	consistent quality	The data/images/videos etc. cannot easilty be viewed by an unauthorized person.
Level 3a	quality standards	The data/images/videos etc. are transmitted according to a standard transmissions protocol.
Level 3b	quality standards	The data/images/videos etc. are appropriately encrypted and decrypted.
Level 4a	quality control	The data/images/videos etc. can be tracked throughout the telemedicine service.
Level 4b	quality control	The data/images/videos etc. and the identities of persons who viewed and edited them, can be tracked.
Level 5a	quality improvement	Causes of delays and incorrectly transmitted data are identified.
Level 5b	quality improvement	Causes of delays and incorrectly transmitted EHRs are continuously addressed.

Capability statements 1a (uncertain), 2a (consistent), 3a (standard) and 4a (control) relate to the transmission process only, while statements 1b, 2b, 3b and 4b define the capability of the process to keep the data secure. The TMSMM does not prescribe how data are to be transmitted or secured, but assesses if the data are securely transmitted. The legal and ethical implications of telemedicine data security are investigated in depth by Jack and Mars (Jack, 2008; Mars, 2009). In the target maturity state (level 5), processes are in place to continuously improve on the data transmission process.

6.4.3 Electronic record management

Any telemedicine service inevitably produces electronic versions of some healthcare data. The concern of the meso and macrolevel capability areas of the *Material* domain is whether the healthcare data are actually kept on record and managed as such. The terms electronic medical record (EMR) and electronic health record (EHR) are often used interchangeably. However, there is a distinct difference between these two:

> An electronic medical record (EMR) is a digital version of the traditional paper-based medical record for an individual. The EMR represents a medical record within a single facility, such as a doctor's office or a clinic.
>
> An electronic health record (EHR) is an official health record for an individual that is shared among multiple facilities and agencies. Digitized health information systems are expected to improve efficiency and quality of care and, ultimately, reduce costs. (ITChannel, 2013)

In the TMSMM, the mesolevel capability area for the *Material* domain relates to the management of EMRs (Table 6.10), while EHR management is the concern of the macrolevel capability area (Table 6.11).

Table 6.10: Capability area: Electronic medical record (EMR) management

Level	**Maturity scale**	**Capability statements**
Level 0	no records	The electronic medical records (EMRs) do not exist.
Level 1a	temporary	The electronic medical records (EMRs) do not exist/exist only in paper format.
Level 1b	temporary	The electronic medical records (EMRs) are kept and stored by user while telemedicine process is in progress.
Level 2a	isolated	The electronic medical records (EMRs) are kept on telemedicine device.
Level 2b	isolated	The electronic medical records (EMRs) are kept on a local databasis specific to telemedicine service.
Level 3a	integrated	The electronic medical records (EMRs) are integrated with hospital information system (HIS).
Level 3b	integrated	The electronic medical records (EMRs) are managed in such a way that the can be transformed into management information.
Level 4a	business intelligence	The electronic medical records (EMRs) are managed in such a way that the can be transformed into management information.
Level 4b	business intelligence	The electronic medical records (EMRs) are routinely transformed into management information and considered by relevant decision makers.
Level 5a	business optimization	Ad hoc management decisions related to telemedicine services are based on this information.
Level 5b	business optimization	Continuous management decisions related to telemedicine services are based on this information.

If these electronic data are transmitted and converted by the right persons at the right time according to an appropriate method, the telemedicine service is successful. However, it cannot be assumed that the electronic data is kept on record and managed as such. Often the electronic data exists only for the duration of the service (maturity level 1) or it is not integrated with other information and record management systems (maturity level 2). For a telemedicine service to achieve a maturity level of 3 in terms of record keeping, the telemedicine data must be integrated with existing information systems, e.g. a hospital information system (HIS) in the case of the mesolevel capability area or existing EHR management records in the case of the macrolevel capability area.

Evelson and Norman (2008) defines *Business Intelligence* (BI) as "... a set of methodologies, processes, architectures, and technologies that transform raw data

Table 6.11: Capability area: Electronic health record (EHR) management

Level	Maturity scale	Capability statements
Level 0	no records	The electronic health records(EHRs) do not exist.
Level 1a	temporary	The electronic health records(EHRs) do not exist/exist only in paper format.
Level 1b	temporary	The electronic health records(EHRs) of telemedicine service are not kept on record after completion of the service.
Level 2a	isolated	The electronic health records(EHRs) of telemedicine service are available to all facilities that took part in process, but not centrally. Duplicates of the record are kept by respective facilities.
Level 2b	isolated	The electronic health records(EHRs) of telemedicine service are available centrally to all facilities that took part in process.
Level 3a	integrated	The electronic health records(EHRs) are linked to an existing EHR management system.
Level 3b	integrated	The electronic health records(EHRs) are integrated with an existing EHR management system.
Level 4a	business intelligence	The electronic health records(EHRs) are managed in such a way that they can be transformed into management information.
Level 4b	business intelligence	The electronic health records(EHRs) are routinely transformed into management information and considered by relevant decision-makers.
Level 5a	business intelligence	Ad hoc management decisions related to telemedicine services are based on this information.
Level 5b	business intelligence	Continuous management decisions related to telemedicine services are based on this information.

into meaningful and useful information used to enable more effective strategic, tactical, and operational insights and decision-making." A maturity level of 4 indicates that transactional data of the EMRs are aggregated and analyzed to show trends and other useful management information. In the target maturity state (level 5) management decisions are based on this information.

The rationale for the formulation of the macrolevel capability statements (electronic health records (EHRs)) are the same as for the mesolevel processes described above. The only difference is that EMRs are contrained to a single facility, such as a doctor's office or a clinic, while EHRs are shared among all multiple facilities and agencies.

6.5 Capability Statements for the *Method* Domain

The capability statements for the capture, diagnose and react processes of the *Methods* domain encompass work procedures. The mesolevel and macrolevel capability areas encompass the institutional and national change processes.

6.5.1 Work procedures

Table 6.12: Capability area: Work procedures

Level	**Maturity scale**	**Capability statements**
Level 0	no innovation	The work procedure does not exist.
Level 1a	*ad hoc*	The work procedure is executed on a trial and error basis.
Level 1b	*ad hoc*	The work procedure differs from person to person and case to case.
Level 2a	effective	The work procedure is executed repeatably.
Level 2b	effective	The work procedure is at least as effective as the traditional healthcare service.
Level 3a	work standards	The work procedure is defined and documented as standard.
Level 3b	work standards	The work procedure is aligned with ethical and legal guidelines.
Level 4a	performance control	Relevant and realistic efficiency measures (outputs and inputs) are defined.
Level 4b	performance control	Efficiency measures are continuously collected and communicated to relevant decision makers.
Level 5a	continuous improvement	The work procedure is proven to be more efficient than the traditional healthcare service.
Level 5b	continuous improvement	The work procedure's effectiveness is continously improved.

On Table 6.12 a maturity level of 1 applies to services that are executed on an *ad hoc*, inconsistent trial and error basis. The difference between *effectiveness* and *efficiency* is often explained as follows: "*Effectiveness* is doing the right things, while *efficiency* is doing things right." A telemedicine service is effective if the desired health outcomes are repeatedly accomplished (level 2). Khoja *et al.* (2013*a*) refer in this regard to the stability of services.

Once this is accomplished, the work procedure can be defined and documented as standard. It is important that this standard should be aligned with ethical and legal guidelines (level 3). Most healthcare services need to be executed according to a certain set of well-defined protocols in order to ensure consistency, integrity and ethical conduct. In most cases these protocols are defined and executed as such, before ICT made telemedicine possible.

Efficiency is typically measured as the ratio between output and input (level 4), e.g. the number of telemedicine triage procedures per hour or the number of physical transferrals avoided as the ratio of the total number of referrals. Examples of typical cost-benefit ratios are "number of diagnoses per specialist hour" (diagnose microlevel process); "number of e-consultations per healthcare worker" (Field, 1996) (react microlevel process) or "consultations per site per week" (Mars and Scott, 2012).

These values only have meaning when compared with, for example, values from previous time periods, industry standards or other similar processes (Field, 1996). For this reason continuous monitoring – and not only once-off measuring – is imperative. The target maturity state (level 5) is where efficiency is not only monitored continuously, but also continuously improved.

6.5.2 Network service

The capability statements for the microlevel data transmission process of the *Method* domain are set out in Table 6.13. The network service provider (e.g. internet service provider/mobile phone operator/wide area network (WAN) provider) determines the method by which the data is transmitted.

Table 6.13: Capability area: Network service

Level	**Maturity scale**	**Capability statements**
Level 0	no innovation	The network service is not available yet/anymore.
Level 1a	ad hoc	The network service is sometimes available. Not a specific service provider.
Level 1b	ad hoc	The network service is mostly available. Not a specific service provider.
Level 2a	effective	The network service is delivered by a specific (set of) service provider(s) with varying service levels.
Level 2b	effective	The network service is delivered by a specific (set of) service provider(s) with consistent service levels.
Level 3a	work standards	The network service-level-agreements (SLAs) are defined.
Level 3b	work standards	The network service-level-agreements (SLAs) are contractually agreed upon.
Level 4a	performance control	The network service levels are measured.
Level 4b	performance control	The network service levels are continuously monitored and penalties applied.
Level 5a	continuous improvement	The network service levels are continuously maintained.
Level 5b	continuous improvement	The network service levels are continuously improved.

The ITChannel (2013) explains that a service-level agreement (SLA) is "a contract between a network service provider and a customer that specifies, usually in measurable terms, what services the network service provider will furnish." Traditionally this contract is between an external service provider and a client. However, it is also becoming standard practice for IT departments (internal service providers) to agree on service levels with their internal customers.

Some examples of service levels are (ITChannel, 2013):

- What per centage of the time services will be available
- The number of users that can be served simultaneously
- Dial-in access availability

Within the context of the TMSMM, the service level agreement is the work standard (maturity level 3) for the transmission process. In this case performance is measured in terms of the service-level agreements. If these agreements are continuously measured and monitored, deviations can be addressed so as to maintain the service level (level 4). Ultimately, these service levels must not only be maintained, but also continuously improved (level 5).

6.5.3 Change management

The implementation of telemedicine services often changes the working routines, allocation of tasks (Mettler, 2011), location of place of work, internal co-ordination, flow of patients (Aas, 2001), business models etc.

The need for deliberate and effective change management is echoed throughout studies on the implementation of telemedicine services (Grigsby *et al.*, 2002; Bangert and Doktor, 2003; Bashshur *et al.*, 2000; Yellowlees, 2005; Mars, 2009; Khoja *et al.*, 2007; Durrani and Khoja, 2009; Edwards, 2011; Chipps and Mars, 2012). Change management is the process of changing processes. Within the context of the TMSMM, change management is positioned as a mesolevel process of the *Methods* domain (Table 6.14).

A champion is a user from the community who takes the role of innovator and advocate. Many authors, for example Araki *et al.* (2007); Wade and Eliott (2012); Mars (2009) and Yellowlees (2005) list the involvement of a so-called champion as a critical factor for the successful implementation of telemedicine services. Maturity level 2 applies when such a champion is either self-appointed or appointed by the institution.

A standard maturity level (level 3) applies to a sustainable institutional commitment to accomplish change. This commitment is demonstrated first by the formal and permanent appointment of a change, agent and second if the change management process also manifests in other business processes, for example, during the budget process or facilities design process.

Whatever the type of model, it is important that the measures that will drive achievement are defined. These measures must be understood and accepted (Vanderwerf and Latifi, 2004). The effectiveness of the change management process is

Table 6.14: Capability area: Change management

Level	Maturity scale	Capability statements
Level 0	not existing	The change management process does not exist.
Level 1a	experiment	The change management process has not been considered.
Level 1b	experiment	The change management process was ineffective. The process regressed back to old method after pilot phase.
Level 2a	bottom-up	The change management process is executed by an entrepreneur.
Level 2b	bottom-up	The change management process is driven by an (at least) self-appointed champion.
Level 3a	top-down	The change management process is integrated with other business processes (e.g. budget, facilities planning, service redesign).
Level 3b	top-down	The change management process is linked to key performance indicators (KPIs).
Level 4a	performance and health indicators	The change management process is linked to key performance indicators (KPIs).
Level 4b	performance and health indicators	The change management process is monitored in terms of these KPIs.
Level 5a	continuous improvement	The change management process addresses deviations from key performance targets.
Level 5b	continuous improvement	The change management process continuously improves on key performance targets.

measured in terms of performance indicators (maturity level 4). Maturity level 5 implies that processes are in place to ensure continuous improvement in terms of these performance indicators.

6.5.4 Policies and strategies

Finch *et al.* (2006) consider *policy context* the as most detrimental factor to the success of teledermatology services. Most of the services studied by them were conceived through high-level central or local health policy support. Where such support did not translate into resources, services failed to become standard practice. The importance and complexity of defining and aligning appropriate policies and strategies with telemedicine services are echoed by many others, e.g. Grigsby *et al.* (2002), Broens *et al.* (2007), Bashshur and Shannon (2009) and Mars and Scott (2010).

The 11 statements of this capability area (Table 6.15) are not sufficient to capture the dynamics of ehealth policies and strategies, but they do indicate the maturation path towards policies and strategies that facilitate the continuous improvement of telemedicine services.

Policies and strategies are normally ignored in the experimental and prototype phase. Often (mostly?) the design of these services is in conflict with existing policies (level 1). Once the service becomes operational, the service should be aligned with existing policies and strategies. This normally happens in a bottom-

Table 6.15: Capability area: National policies and strategies

Level	Maturity scale	Capability statements
Level 0	not existing	Policies and strategies related to the telemedicine service are not known.
Level 1a	experiment	Policies and strategies are ignored at this stage.
Level 1b	experiment	Policies and strategies are in conflict with the telemedicine services.
Level 2a	bottom-up	The change management process : the service is adapted to fit the strategies.
Level 2b	bottom-up	The change management process : the service is adapted to fit the policies and strategies.
Level 3a	top-down	The change management process : strategies is adapted to fit the telemedicine services.
Level 3b	top-down	Policies and strategies are aligned with the processes of the telemedicine service.
Level 4a	performance and health indicators	Policies and strategies are linked to health indicators.
Level 4b	performance and health indicators	Policies and strategies facilitate the systematic evaluation of this telemedicine service.
Level 5a	performance and health indicators	Policies and strategies facilitate the sharing of best practices and management of knowledge of this service.
Level 5b	performance and health indicators	Policies and strategies continuously facilitate the dissemination of best practices.

up manner (level 2) when the service is adapted to fit the policies and strategies. A more mature approach is a top-down approach (level 3) where the new policies and strategies are adapted to advance the services. Maturity level 4 always concerns the quantitative measurement of the processes within the capability areas. In this case realistic and appropriate health indicators should be in place.

> Government stewardship includes creating a learning environment, where projects are evaluated systematically and where collaboration and sharing of knowledge can contribute to a central repository of evidence on [telemedicine] mHealth, which in turn can influence policy and practice (Leon *et al.*, 2012).

Yellowlees (1997) also considered the "documentation and publication of ideas, methods, outcomes and further research questions" as a core principle for any telemedicine service. In the the target maturity state (level 5) policies and strategies should facilitate the sharing of best practices and the continuous dissemination of best practices.

6.6 Capability Statements for the *Money* Domain

Jackson and McClean (2012) consider cost-related measures as the most neglected criteria in the assessment of telemedicine services.

The maturity of the microlevel telemedicine service – as far as the money-domain is concerned – is measured in terms of the costs to operate and maintain this service. At the macrolevel, the financial sustainability of the *Money* domain is considered, first, with respect to the specific telemedicine service and, second at a higher level, with respect to the macro-economic healthcare system.

6.6.1 Operational costs

The capability statements for the microlevel processes are identical for the capture, diagnose, react and transmit process (refer to Table 6.16).

Table 6.16: Capability area: Operational costs

Level	Maturity scale	Capability statements
Level 0	no	The operational costs are not funded.
Level 1a	R&D/entrepeneur	The operational costs are not considered by developers/entrepeneur.
Level 1b	R&D/entrepeneur	The operational costs are considered and covered by seed funds while service is in development.
Level 2a	consistent, but temporary	The operational costs will be covered on short term by seed funds.
Level 2b	consistent, but temporary	The operational costs will be covered on long term by seed funds.
Level 3a	consistent and permanent	The operational costs are included partially as a standard budget item.
Level 3b	consistent and permanent	The operational costs are included fully as a standard budget item.
Level 4a	accountability	The operational costs' are a reporting item of the accounting system.
Level 4b	accountability	The operational costs' reports are routinely scrutinized to ensure optimal use of funds.
Level 5a	cost optimization	Non-value-adding activities are continuously identified.
Level 5b	cost optimization	Non-value-adding activities are continuously eliminated.

Maturity levels 1 and 2 apply when the operational costs are provided by external entities, either for purposes of research and development (level 1) or for philanthropic reasons by external donors. These funding modes are not sustainable. For financial sustainability, it is mandatory that operational expenses are covered as part of the standard budgeting process of the governing organization (maturity level 3). This can also include agreements with health insurers. Accountability (level 4) implies that the cost associated with each microlevel telemedicine service is measured and monitored. Cost-optimization (level 5) is a deliberate effort to continuously eliminate non-value adding activities.

6.6.2 Business models

A business model describes the rationale of how an organization creates, delivers, and captures value (Osterwalder and Pigneur, 2010). On mesolevel the focus is on how the inter-organization creates, delivers and captures value from the telemedicine services (Table 6.17). On macrolevel, the national business case for the delivery of the telemedicine service is considered (Table 6.18). The development of business models for healthcare service providers is difficult because the value that is created, delivered and captured cannot always be expressed in monetary terms. This is especially true for public healthcare systems.

Table 6.17: Capability area: Business model

Level	Maturity scale	Capability statements
Level 0	no	The interorganizational business model is not available yet/anymore.
Level 1a	fragmented	The interorganizational business model has never been considered.
Level 1b	fragmented	The interorganizational business model has never been considered for the inter-organization that spans the telemedicine service.
Level 2a	synergy	The interorganizational business model has been considered for the inter-organization that spans the telemedicine service.
Level 2b	synergy	The interorganizational business model includes all stakeholders.
Level 3a	sustainable	The interorganizational business model will sustain without donor funds/ seed funds.
Level 3b	sustainable	Costs and benefits are realistically measured.
Level 4a	health economics	Costs and benefits are realistically measured.
Level 4b	health economics	Cost-benefit analyses are continuously performed.
Level 5a	value optimzation	How the organization creates, delivers and captures value are continuously improved.
Level 5b	value optimzation	The interorganizational business model is successfully replicated elsewhere.

6.6.3 National business case

The aim of the capability statements for these two capability areas is not to provide guidance towards the development of a business model - an investigation into business models for the delivery of telemedicine services warrants an entire new study. Instead, these capability statements measure maturity in terms of the extent to which the business model is embraced by all stakeholders.

Level 1 (fragmented) implies that a business model was never considered for the inter-organization that spans the telemedicine services (mesolevel) or for the national health system (macrolevel). Level 2 indicates some synergetic attempt to define a business model. Level 3 indicates that a business model exists according to which the inter-organization (mesolevel) can create, deliver and capture value in a sustainable way.

Table 6.18: Capability area: National business case

Level	Maturity scale	Capability statements
Level 0	no	The national business case is not available yet/anymore
Level 1a	fragmented	The national business case has never been considered.
Level 1b	fragmented	The national business case has never been considered.
Level 2a	synergy	Pockets of organized value creation.
Level 2b	synergy	Nationally organized value creation.
Level 3a	sustainable	National funding structures are in place.
Level 3b	sustainable	Processes for the reimbursement of telemedicine services are in place.
Level 4a	health economics	The health-economic impact of the service are measured.
Level 4b	health economics	The national business case: health economics metrics are used as decision input to health systems strengthening.
Level 5a	health economics	The service has a significant socio-economic impact on the nation.
Level 5b	health economics	The impact of the service on the socio-economic well-being of the nation is continously expanded.

Health economics is a branch of economics concerned with the functioning of macro-economic healthcare systems, as well as health-affecting behaviours and interventions – such as the use of technology (Wikipedia). Health economists all over the world are grappling still with the challenge of financially justifying telemedicine services (Bashshur *et al.*, 2005) and no clear-cut financial model has yet been developed. It is also not the intention of the TMSMM to provide answers concerning how the financial sustainability and return on investment can be measured and managed, but merely *if* these aspects are being managed and measured.

A maturity level of 4 implies that some form of cost metric is part of the business model. Jackson and McClean (2012) conducted a systematic literature review to identify cost metrics and methods within the context of telemedicine and ehealth:

Operational costs: A single measure for time of healthcare worker, facility, utility, technology and support service.

Healthcare professional costs: Time and financial costs measured for healthcare workers, which are not included in operational costs.

Cost effectiveness analysis: Comparison between incremental costs and incremental health effects of a service.

Cost utility analysis: Measurement of health improvements in terms of quality adjusted life years (QALYs). Khoja *et al.* (2013*a*) also included disability-adjusted life years (DALYs) in their cost utility analysis.

A cost-benefit analysis: Benefits of the service are translated into monetary terms. The cost-benefit ratio is the ratio between cost benefits and actual costs. However, quantifying benefits of health interventions is easier said than done.

Costs consequence analysis: Descriptive comparison of the costs and outcomes of an intervention.

Cost minimization analysis: The maximal benefit to the population for the least cost (Drummond *et al.*, 2005). The assumption is made that the new service does not change the clinical effectiveness, efficiency or quality of the service.

Cost of hospitalization: The costs of treating patients in terms of costs of hospital accommodation, medicines, healthcare services and other in-hospital costs.

Changes in mortality rates: A health-economic measure of changes in mortality rates associated with a healthcare intervention. These measures only become available once the service is routinely used (Jackson and McClean, 2012).

On maturity level 5 the business model is continuously improved and also replicated elsewhere (mesolevel). At the macrolevel the concern of health economics is the socio-economic impact of the telemedicine service on the nation.

6.7 Capability Statements per Maturity Level

A capability statement is a generic statement that describes characteristics of a process as it applies to a specific maturity level. In this chapter the capability statements were described and supported by evidence from the state of the art. These statements were organized along the capability areas.

As design principle, exactly two capability statements are defined for each maturity level for each capability area. This design principle, together with the dimensional design of the conceptual TMSMM makes it possible that the capability statements are also organized along maturity levels, as suggested by Figure 6.3. For example, Figure 6.4 shows all capability statements as it is defined on maturity level 3. Similar sheets for the other maturity levels are shown in Appendix F.2 and demonstrate design requirement 11.

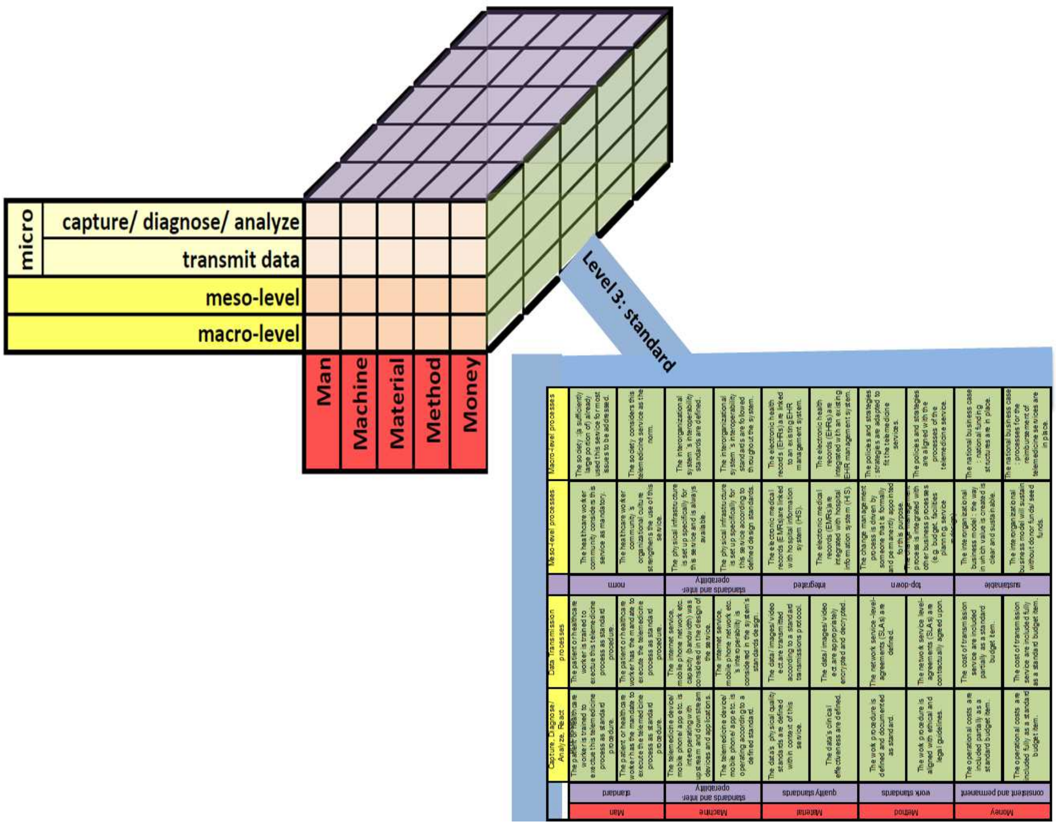

Figure 6.3: Conceptual TMSMM

		Capture, Diagnose/ Analyze, React	Data Transmission processes		Meso-level processes	Macro-level processes
Man	standard	The patient or healthcare worker is trained to exectue this telemedicine process as standard procedure.	The patient or healthcare worker is trained to exectue this telemedicine process as standard procedure.	norm	The healthcare worker community considers this service as mandatory.	The society :(a sufficiently large portion of) already used this service for most issues to be addressed.
		The patient or healthcare worker has the mandate to execute the telemedicine process as standard procedure.	The patient or healthcare worker has the mandate to execute the telemedicine process as standard procedure.		The healthcare worker community 's organizational culture strengthens the use of this service.	The society considers this telemedicine service as the norm.
Machine	standards and inter-operability	The telemedicine device/ mobile phone/ app etc. is interoperating with upstream and downstream devices and applications.	The internet service, mobile phone network etc. capacity (bandwidth) was considered in the design of the service.	standards and inter-operability	The physical infrastructure is set up specifically for this service and is always available.	The interorganizational system 's interoperability standards are defined.
		The telemedicine device/ mobile phone/ app etc. is operating according to a defined standard.	The internet service, mobile phone network etc. 's interoperability is considered in the system's standards design.		The physical infrastructure is set up specifically for this service according to defined design standards.	The interorganizational system 's interoperability standards are followed throughout the system.
Material	quality standards	The data's physical quality standards are defined within context of this service.	The data/ images/ video ect.are transmitted according to a standard transmissions protocol.	integrated	The electronic medical records (EMRs)are linked with hospital information system (HIS).	The electronic health records (EHRs) are linked to an existing EHR management system.
		The data's clinical effectiveness are defined.	The data/ images/ video ect.are appropriately encrypted and decrypted.		The electronic medical records (EMRs)are integrated with hospital information system (HIS).	The electronic health records (EHRs) are integrated with an existing EHR management system.
Method	work standards	The work procedure is defined and documented as standard.	The network service -level-agreements (SLAs) are defined.	top-down	The change management process is driven by someone that is formally and permanently appointed for this purpose.	The policies and strategies : strategies are adapted to fit the telemedicine services.
		The work procedure is aligned with ethical and legal guidelines.	The network service level-agreements (SLAs) are contractually agreed upon.		The change management process is integrated with other business processes (e.g. budget, facilities planning, service redesign)	The policies and strategies are aligned with the processes of the telemedicine service.
Money	consistent and permanent	The operational costs are included partially as a standard budget item.	The cost of transmission service are included partially as a standard budget item.	sustainable	The interorganizational business model : the way in which value is created is clear and sustainable.	The national business case : national funding structures are in place.
		The operational costs are included fully as a standard budget item.	The cost of transmission service are included fully as a standard budget item.		The interorganizational business model will sustain without donor funds/ seed funds.	The national business case : processes for the reimbursement of telemedicine services are in place.

Figure 6.4: Capability statements viewed per maturity Level 3

6.8 Conclusion

The purpose of this chapter was to present the capability statements for each capability area. These statements were framed within the conceptual TMSMM. The formulation was informed by the state of the art as well as insights gained in the application of earlier versions of the TMSMM, within the parameters of DRs 8, 9, 10, 11 and 12.

This concludes the second phase in the description of the TMSMM. The third and final phase involves the methodology that is to be followed when using the TMSMM to assess a telemedicine service. This is the focus of the next chapter.

Chapter 7

Maturity Assessment Methodology

This is the third of three chapters that describe the TMSMM and the iterative design process that was followed to develop it. The conceptual TMSMM and capability statements were described in chapters 5 and 6 respectively. This chapter describes the assessment methodology for the TMSMM. In doing so, Research Question 5.3 is addressed: "How should the service data be captured, stored, aggregated and analyzed to meet the design requirements?"

7.1 Iterative Design Process

The iterative design approach, as it applies to this chapter, is shown in Figure 7.1. The process has five inputs, namely (1) the design requirements, (2) the conceptual TMSMM, (3) existing data warehousing techniques, (4) capability statements and (5) intermediary applications of the TMSMM.

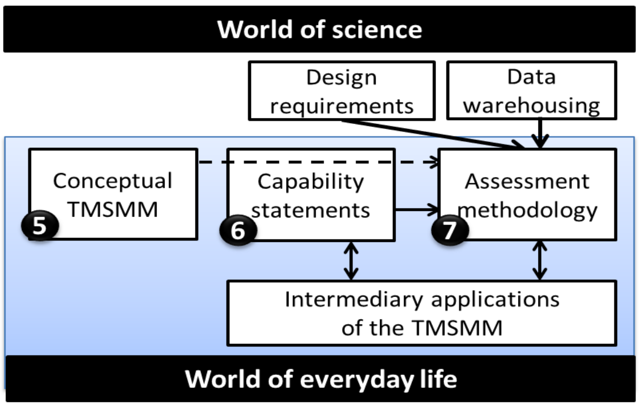

Figure 7.1: Methodology to arrive at user specifications

7.1.1 Design requirements

The following four design requirements are addressed in this chapter:

DR 3: Based on this assessment, the TMSMM indicates further actions.

DR 5: The maturity assessment methodology can be followed easily and intuitively.

DR 6: Role players from multiple disciplines can use the TMSMM to describe and assess the telemedicine service on the detail level they are dealing with it.

DR 7: Results from a collection of individual service assessments can be aggregated to an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic level decision-makers.

Each of the phases of the assessment methodology, as indicated in Figure 7.2, focusses on one or more of these design requirements. First, individual services are described and assessed, with DR 5 and 6 in mind (Section 7.3). Then a report is generated for each individual service, indicating further actions (DR 3). This phase is described in Section 7.4. The third phase (Section 7.5) involves the aggregation and analysis of a cohort of services. Such cohorts are, for example, services within a specific health system or geographical region or with respect to a certain telemedicine specialization or technology driver. This must be done in such a way that DR 7 is addressed.

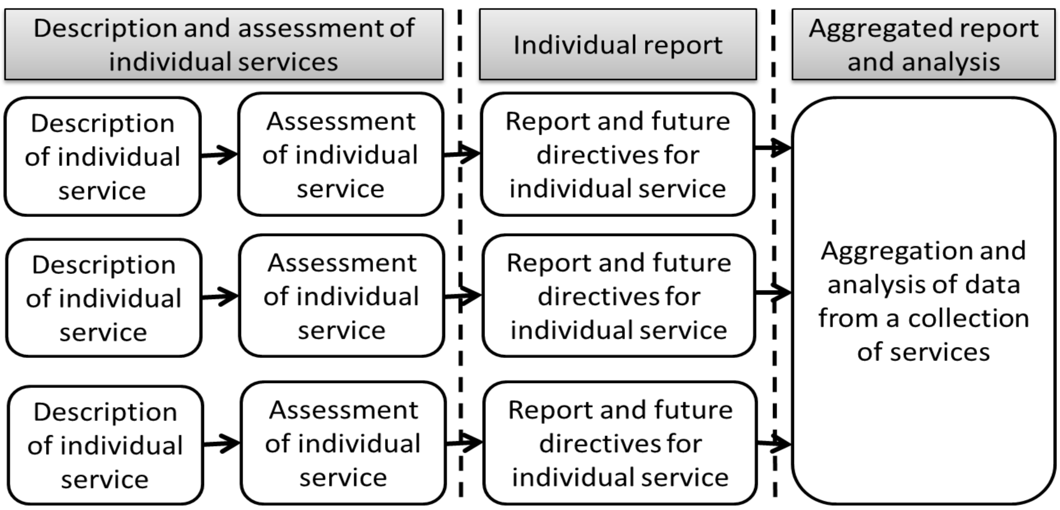

Figure 7.2: Phases of the assessment methodology

7.1.2 The conceptual TMSMM

The conceptual TMSMM is designed along 30 capability areas (6 processes on the *Service* dimension multiplied by 5 domains along the *Domain* dimension). These capability areas provide a framework for information about a telemedicine service. Because of the dimensional design of the conceptual TMSMM, the telemedicine service descriptions and assessment data are stored in a multidimensional data model. The design of a multidimensional data model allows the use of existing data warehousing techniques, such as online analytical processing (OLAP) operations, to create different reports through the aggregation of data.

7.1.3 Capability statements

A scale is an instrument with which a quantitative value is associated with an often intangible concept, for example weight. Similarly, the sets of capability statements are instruments with which a quantitative value is awarded to an intangible concept such as maturity. The unit of measurement is the maturity level. This instrument is an integral part of the assessment methodology.

7.1.4 Intermediary applications of the TMSMM

From the world of everyday life examples of actual telemedicine services were used as test cases to align assessment methodology with the conceptual TMSMM, the capability statements and design requirements. Van Zyl (2012), Viljoen (In process) and Hartmann (In process) contributed to this process as part of their respective posgraduate studies.

7.1.5 Case studies

In Appendix D the execution of this assessment methodology is demonstrated by means of a set of case studies. The first two phases (refer to Figure 7.2) are demonstrated by means of two unrelated individual cases, namely a teleophthalmology service in pilot phase and a private sector teleradiology service.

7.1.5.1 A teleophthalmology service in pilot phase

Also refer to Appendix D.1.1. This service aims to support nurses in rural clinics of South Africa in the screening of diabetes patients for diabetic retinopathy, by means of single field fundus photography. An opthalmoscope system was developed by Blanckenberg *et al.* (2011) (refer to Figure D.2).

A standard Welch Allyn Panoptic ophthalmoscope is mounted to a digital camera. The images captured by the digital camera are sent by wireless connection to a smartphone on which custom software is installed. An ophthalmologist, typically situated at a tertiary hospital, then log into the web platform to retrieve the images and submit a diagnosis upon which the nurse receives an SMS on the smartphone and can review the recommendation and treatment prescription (Blanckenberg *et al.*, 2011). Blanckenberg *et al.* (2011) published a detail description of this service. The primary author of this paper, Dr Mike Blanckenberg, were one of the experts that were consulted in the process of verification and validation. The maturity assessment of this service were executed as part this expert interview.

7.1.5.2 A private sector teleradiology service

Also refer to Appendix D.1.2. This is the only teleradiology service included in this study that is taken from the private healthcare system of South Africa. The radiology information system (RIS) is integrated with the hospital information system (HIS) as well as an Electronic Health Record (EHR) system. The process start where the EHR is retrieved from the HIS. The referral information already appear on the system.

The radiographer then follow a well defined work procedure to take the radiograph. As soon as the radiographer is satified that the radiograph is capture according to an acceptable quality, the image is saved on the server of the EHR system. The radiograph is transmitted from the radiography centre to the server via the communications network of the private hospital group. The radiograph is then pushed to a radiologist within the hospital group, based on the availability and expertise of the radiologist. The referring doctor are notified once the EHR is updated to include the conclusion and recommendation.

7.1.5.3 Cohort case studies

The third phase are demonstrated by means of two cohort studies. These cohorts were decided upon after the data for all 28 services was collected. The following criteria were used to decide on the services for the cohort studies:

- Each cohort must represent at least 25 per cent of the services.
- Each cohort must have a unique set of stakeholders that may be interested in this study.

7.1.5.4 Teleradiology cohort

Also refer to Appendix D.2. This study includes all teleradiology services from the list of 28 services, irrespective of technology driver or healthcare institution. External stakeholders that may be interested in this cohort study are radiologists and radiographers that make use of teleradiology or who are interested in doing so; providers of teleradiology technology and infrastructure, for example SITA (State Information Technology Agency); telemedicine co-ordinators responsible for the implementation of telemedicine services within a specific context as well as high-level policy makers.

7.1.5.5 Hospital network cohort

Also refer to Appendix D.3. This study includes all telemedicine services at a specific hospital network, irrespective of specialization or technology driver. The target external audience for this cohort study is typically hospital superintendents and regional managers and telemedicine co-ordinators.

More cohort studies can be executed, depending on the quantity and nature of individual telemedicine services described and assessed, as well as the type of management information required. In the section 9.3.2.1 and section 9.3.2.2 findings from each of these cohort studies are shared as part of the validation of the TMSMM.

7.2 Maturity Assessment Resources

The following should be taken into account with respect to the participants as well as the assessment tool:

7.2.1 Participants

The description and assessment of an individual service can be done by any person or group of persons from multiple disciplines that are knowledgeable concerning all facets of the service. If more stakeholders are involved, the assessment process will also contribute to communication between and buy-in from stakeholders.

7.2.2 Facilitator

At least one person must fulfill the role of facilitator. This person must understand the design of the conceptual TMSMM and appreciate how the capability statements relate to the maturity level. Ideally, the same facilitator should be used for the assessment of a cohort of services. It is common practice with respect to many other maturity models that the assessment is facilitated by a person who is specifically trained for this purpose. A detailed procedure for the training of TMSMM facilitators does not fall within scope of this study. It is discussed in Section 10.4 as one of the areas for further development.

7.2.3 Assessment tool

The TMSMM consists of 5 dimensions, 30 capability areas, each with 11 capability statements, which is applied to the description and assessment of each service. To get a comprehensive picture of telemedicine services for a specific cohort, as many services as possible must be assessed. It is practically possible (although tedious) to do the individual assessment on paper, but a computer application is needed to aggregate and analyze the data of a cohort of services. The assessment methodology does not specify the use of a particular method or technology to capture and analyze data. In this chapter functional specifications are provided according to which such an assessment tool can be used, appropriate to the context of the study [1].

7.3 Description and Assessment of Individual Services

The following functional specifications apply to this phase of the assessment methodology.

1. Each telemedicine service has its own input sheet.
2. All capability areas are described on one sheet.
3. The participant(s) can define an infinite number of microlevel processes, depending on the complexity of the service.
4. The participant(s) indicates the type of microlevel service (capture, analyze, diagnose, transmit)[2].
5. The participant(s) describes the microlevel telemedicine service by completing the sentences provided by an input form, similar to the one shown in Figure 7.3). In doing so, each capability area is described.
6. The input form includes one line each for the meso and macrolevel processes. The descriptions for these capability areas are not a user input. It is taken directly from the TMSMM.
7. The generic maturity scale and domain-specific maturity scale of the TMSMM are the headings for the capability statements.
8. When a participant(s) selects a certain capability area, the capability statements for that specific capability area should be considered. [3]

[1] The assessment tool that was developed and used for purposes of this study utilizes the pivot-table and data analysis functions of MS-Excel. Furthermore, instead of a paper-based assessment interface, MS-Excel together with Visual Basic coding enables the capturing of data directly into the database.

[2] The assessment tool that was developed and used for purposes of this study presented an input mask which guided the participants to provide the appropriate descriptions for each capability area for each process, as shown in Figure 7.3

[3] The assessment tool that was developed and used for purposes of this study, automatically presented the appropriate statements, based on the capability area under consideration. The specific user description is concatenated with the capability statement to enhance intuitive use. An example is shown in Figure 7.4.

9. When the user select the appropriate capability statement for a capability area, the maturity value is recorded together with the description of the capability area. Eleven capability statements are available for 5 levels. The first capability statement has a value of 0. The values increase in increments of 0.5, with a maximum value of 5[4].

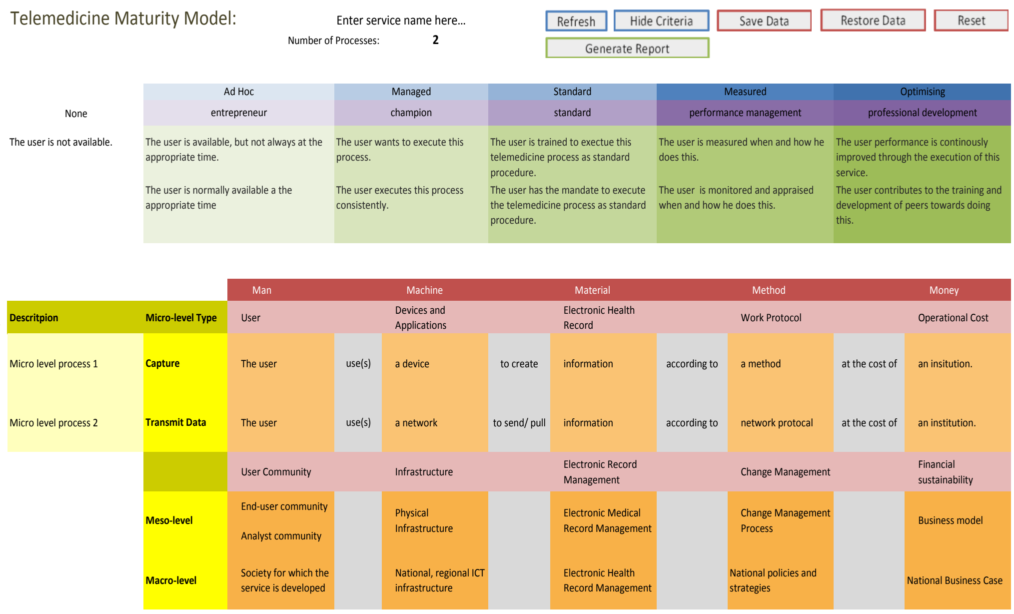

Figure 7.3: Input mask for microlevel processes

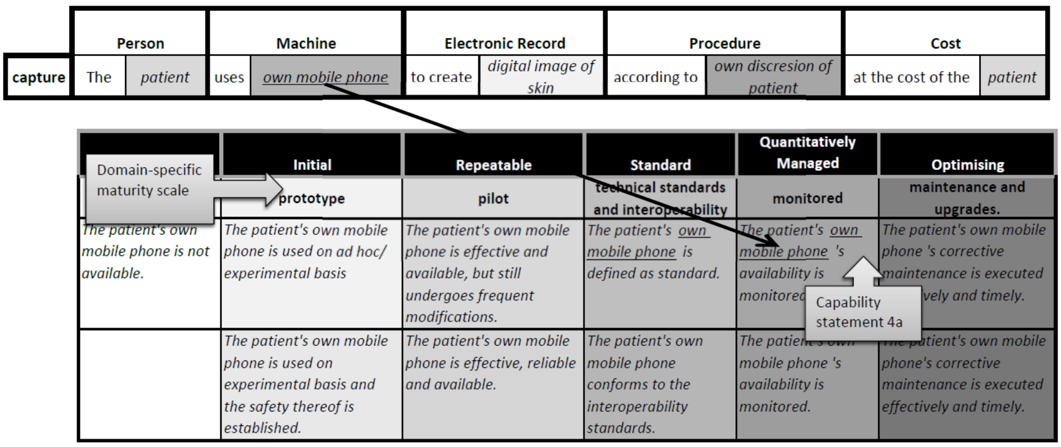

Figure 7.4: Context-specific capability statements per process area

[4]The assessment tool that was developed and used for purposes of this study adjusted the shade or color of the input block in relation to the selected maturity level.

The two individual case studies which are included in Appendix D (sections D.1.2 and D.1.1) adhere to the functional specifications listed above. There are an infinite number of other technical designs that will also satisfy the the functional specifications. These sheets demonstrate one such way and thereby confirm the feasibility of the functional specifications.

7.4 Reports on Individual Services

Design Requirement 3: Based on this assessment, the TMSMM indicates further actions.

The capability statements and maturity levels accumulate. Each higher level statement also includes the preceding lower level statements. Therefore, further actions can be based on follow-up capability statements. However, the completed input sheets themselves do not explicitly state these follow-up capability statements [5]. For this reason a report must be created for each service, indicating the description of the service, the current maturity level as well as guidelines for further action, based on follow-up capability statements. This report can also be used as means of communication and education amongst stakeholders from multiple disciplines.

The functional specifications for a report on an individual Service are as follows:

1. The description for each micro, meso- and macrolevel process is replicated chronologically.
2. For each capability area, the guidelines for further action are provided, based on the value of the maturity level. These guidelines are taken from the guidelines sheet (Appendix F.3). The guidelines sheet comprises the capability statements for the microlevel processes which are rephrased so that it reads as a guideline, rather than a capability statement. As the TMSMM evolves from descriptive to prescriptive maturity model (refer to Section 3.2), it is expected that the *Guideline Sheet* also evolves.

As in the previous section the individual case studies (Sections D.1.2 and D.1.1) demonstrate that the functional specifications for this component met by the tool that was used for purposes of this study.

[5]The assessment tool that was developed and used for purposes of this study provided a maturity dashboard in that the maturity level for each capability area is indicated by means of shading. However, this dashboard in itself does not indicate future actions

7.5 Aggregated Analysis

The third phase involves the aggregation and analysis of a cohort of services (Section 7.5.1). Such cohorts are, for example, services within a specific health system/ geographical region or with respect to a certain telemedicine specialization or technology driver. Analysis of aggregated results can indicate, for example, areas of exceptionally low or high maturity, the variation in maturity levels and also the correlation between the different maturity domains.

Two cohort case studies were executed for purposes of this study. Each of these studies are included as a separate appendix:

Appendix D.2: A cohort of nine teleradiology services from different hospital networks

Appendix D.3: A cohort of seven different telemedicine services from one hospital network in South Africa

7.5.1 Data warehousing

The dimensional design of the conceptual TMSMM makes it possible for the telemedicine service descriptions and assessment data to be stored as a multidimensional data model. This data model provides the structure for the data warehouse. The so-called *fact table* is central to the data warehouse. Jiawei and Kamber (2001) explains that a *fact* is a central theme around which a multidimensional data model is organized, for example sales. This is always a quantitative measure. In the case of the TMSMM, the value of the maturity level constitutes the fact.

Each line of the fact table contains exactly one fact, together with other information concerning the entity, such as the service ID and the capability area ID. This information is often linked to other tables, for example a table with information concerning the telemedicine service (i.e. service ID, name of service, specialization, geographical information, name of facilitator, date of assessment etc.). The fact table, together with these other tables, forms the data mart.

The following functional specifications apply:

1. The assessment data are captured in a fact table, with at least the following fields:
    - 1.1. The value of the maturity level (Fact)
    - 1.2. The capability area ID
    - 1.3. The service ID
    - 1.4. The description of the capability area for that specific service

The assessment methodology does not prescribe the detail design of the data mart. Attributes can be added depending on the context of the overarching study and the context of the cohort.

2. The data must be stored on a technological platform that allows online analytical processing (OLAP) operations, such as *roll-up*, *slicing* and *drill-down*.

7.5.2 Data aggregation

Figure 7.5 shows the logical presentation of the multidimensional data model as well as the OLAP operations and data analyses. The images representing each of these operations are taken from the teleradiology cohort case study (Appendix D.2).

7.5.2.1 The logical presentation

The logical presentation of the multidimensional data model for the TMSMM interface is central to Figure 7.5. According to Jiawei and Kamber (2001) the actual physical storage of such a multidimensional data model may differ from its logical representation. The logical model has exactly the same dimensions as the conceptual TMSMM, namely the service dimension and the domain dimension. The maturity scale which formed a third dimension of the TMSMM, is collapsed. The maturity level is captured as a non-dimensional fact.

7.5.2.2 Concept hierarchy of service dimension

Jiawei and Kamber (2001) explains that a "concept hierarchy defines a sequence of mappings from a set of low-level concepts to higher level, more general concepts. They allow raw data to be handled at higher, generalized levels of abstraction. "

The concept hierarchy for the *Service* dimension is shown in Figure 7.6. For each layer of the concept hierarchy an attribute field is created somewhere in the data mart. In this way, the position of each fact relative the concept hierarchy is recorded in the data warehouse. This structure is particularly useful for roll-up and slice operations (Jiawei and Kamber, 2001), as shown in Figure 7.5.

7.5.3 Data analysis

The reports that are created by this operation lends itself to further data analysis in the form of correlation matrices and box-plots

7.5.3.1 Correlation matrix

A correlation matrix shows the pearson pair-wise correlation between a set of variables.

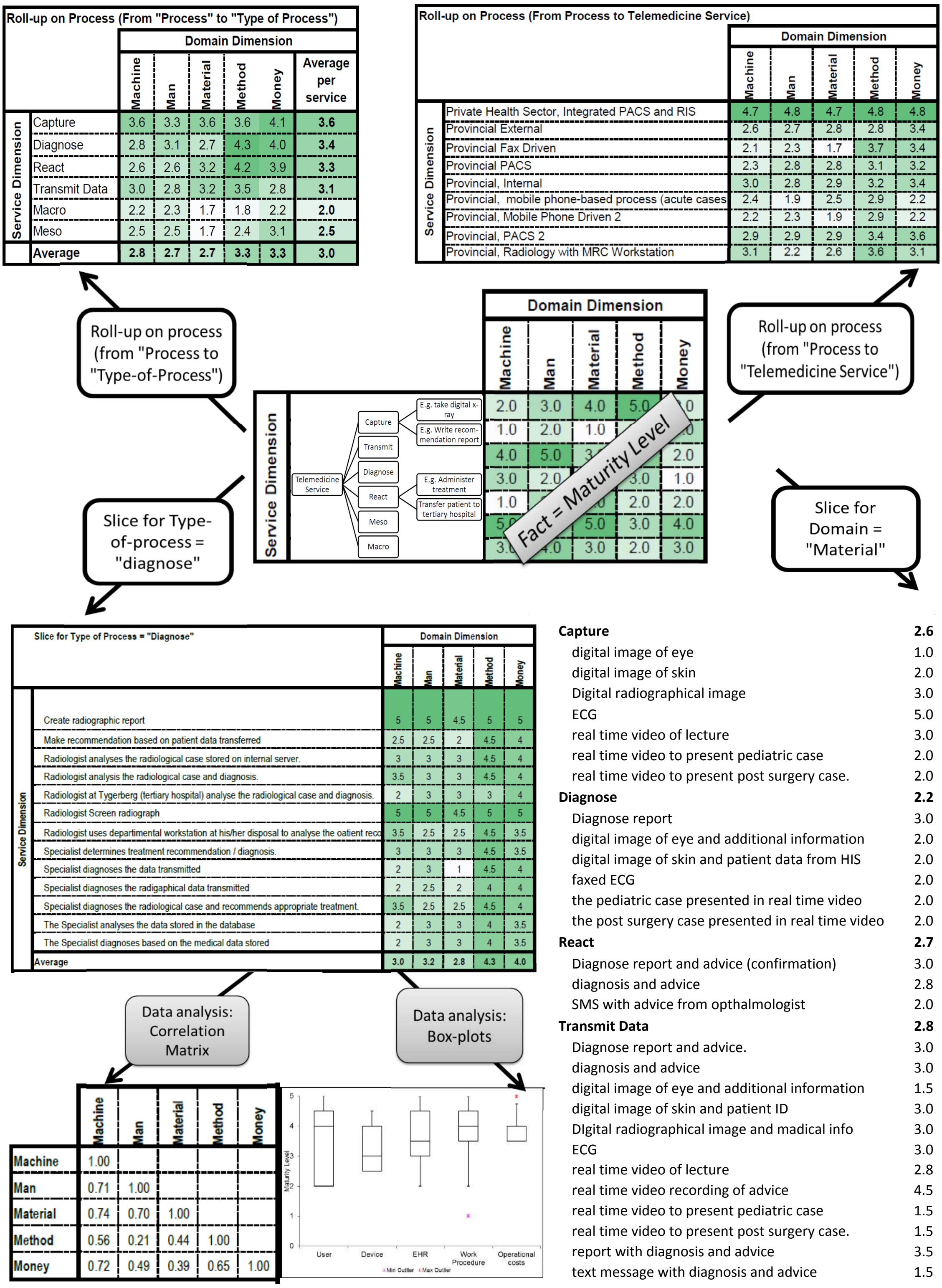

Figure 7.5: The logical multidimensional data model and OLAP operations

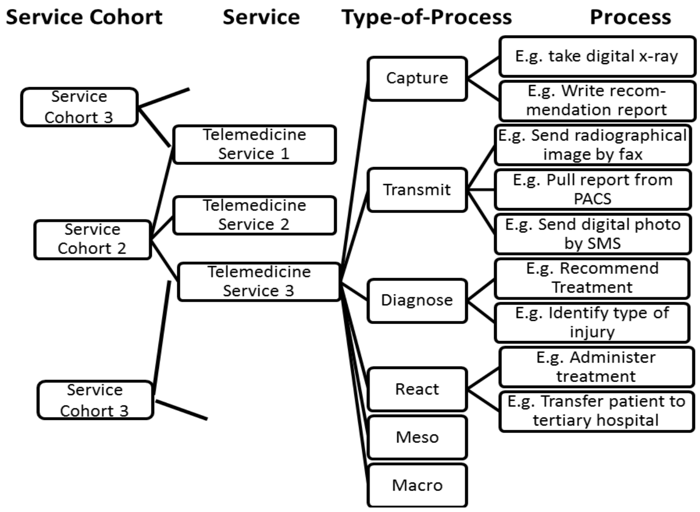

Figure 7.6: Concept hierarchy of service dimension

7.5.3.2 Box-plots

A boxplot is a way of summarizing a set of data measured on an interval scale. It is often used in exploratory data analysis. It is a type of graph which is used to show the shape of the distribution, its central value, and variability. The picture produced consists of the most extreme values in the data set (maximum and minimum values), the lower and upper quartiles, and the median.

7.6 Conclusion

This chapter described an assessment methodology to use the TMSMM for the purpose for which it was developed, namely to assess telemedicine services and to guide and educate stakeholders towards the initialization, standardization and optimization of these services. In answering Research Question 5.3 this assessment methodology includes the methods for capturing (Section 7.3), reporting (Section 7.4) , warehousing (Section 7.5.1), aggregation (Section 7.5.2) and cohort analysis (Section 7.5.3) of the telemedicine service data.

Research Question 5.3: How should the service data be captured, stored, aggregated and analyzed to meet the design requirements?

In this chapter it was shown how design requirements 3, 5, 6 and 7 are addressed by the maturity assessment methodology. The purpose of the next chapter is to verify whether these four design requirements, as well as the requirements applicable to the previous two chapters, are satisfied.

Chapter 8

Verification

The purpose of this study is to find or develop a maturity model for telemedicine services that can be used to describe assess telemedicine services and guide and educate stakeholders towards the optimization thereof. Design requirements for such a model were defined in Chapter 3. In Chapter 4 existing frameworks were evaluated against these design requirements. No such framework was found. The development and design of the new TMSMM were described in chapters 5,6 and 7. This chapter responds to Research Question 6: "Does the TMSMM satisfy all the design requirements?"

8.1 Verification Methodology

Figure 8.1 is the research roadmap for chapters 8, 9 and 10. Research design elements from Chapter 1 are positioned in the green block and serve, together with the design requirements from Chapter 3, as controls for the processes followed throughout chapters 8, 9 and 10. The design requirements control the verification process documented in this chapter.

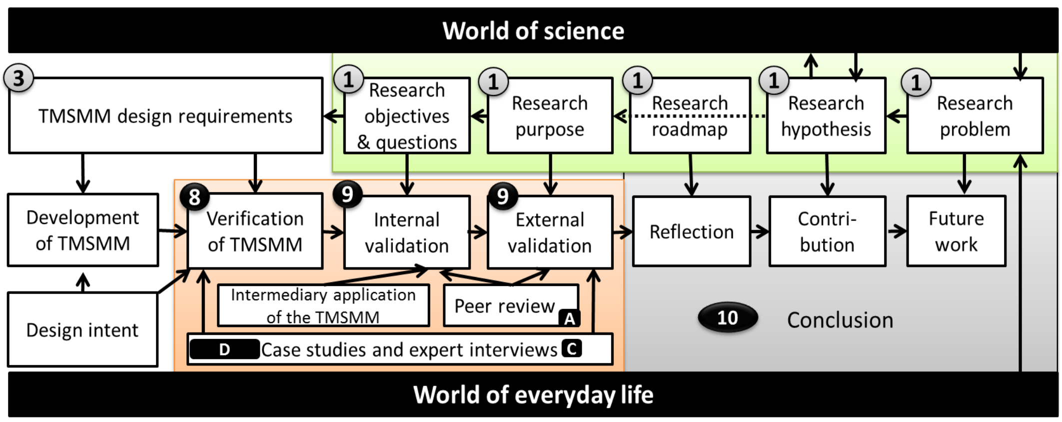

Figure 8.1: Research roadmap: Verification, validation and conclusion

Horizontal arrows indicate the research sequence and the upwards arrows direct the inputs to the research process. The verification process has three inputs as listed below. In the sections that follow, the findings relevant to each particular input are mapped against design requirements:

Design intent: Section 8.2 is a retrospective view on the design process, indicating how the design requirements were intentionally considered, while the TMSMM was developed.

Case studies: The TMSMM was applied to 28 individual services, from which 3 cohort case studies were drawn. The execution of these case studies and their relevance to the design requirements are discussed in Section 8.3.

Expert interviews: Six of the persons who were involved in the above-mentioned case studies, were asked specific questions directly related to the design requirements (Section 8.4).

In Section 8.5, all of the evidence from the previous chapters are put together as proof that all of the design requirements are met.

8.2 Retrospective View on the Design Process

All design requirements were considered and referenced in the design and development of the conceptual model (Chapter 5), the capability statements (Chapter 6) as well as the assessment methodology (Chapter 7). In this section each design requirement are considered respectively and retrospectively in order to verify that it was considered as part of the design process.

DR 1: The domain dimension represents all areas of concern applicable to the telemedicine services. The service dimension encompasses all layers and sub-processes that a telemedicine service comprises. With each of the several design iterations executed, these dimensions were adapted so that they include all aspects relevant to the telemedicine service.

Each cell of this matrix respresents one capability area. In Section 5.4 these two dimensions are brought together to form a matrix, according to which any telemedicine service can be described. This matrix also forms the basis for the service description phase of the assessment methodology (Section 7.3).

DR 1:	The TMSMM can describe any healthcare service that is delivered over a distance (telemedicine service).
DR 2:	The TMSMM enables the assessment of the maturity of this service.
DR 3:	Based on each service assessment, further steps towards the achievement of the target maturity state are indicated.
DR 4:	The TMSMM can be used as basis for education and explaining standards.
DR 5:	The maturity assessment methodology can be followed easily and intuitively.
DR 6:	Role players from multiple disciplines can use the TMSMM to describe and assess the telemedicine service on the detail level they are dealing with it.
DR 7:	Results from a cohort of individual service descriptions and assessments can be aggregated along all dimensions to an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic level decision-makers.
DR 8:	The TMSMM is not directly tied to any standards, technologies or concrete implementation details.
DR 9:	The capability statements are mutually exclusive.
DR 10:	The capability statements are collectively exhaustive.
DR 11:	Descriptions of capability statements clearly relate to and discriminate between maturity levels.
DR 12:	The capability statements and maturity levels accumulate. Each level and statement also includes the preceding lower level statements.

DR 2: The maturity scale forms a third dimension of the conceptual TMSMM. Section 5.5 provides a domain-specific maturity scale, which is used as basis for assessment of each of the capability areas of the above-mentioned matrix. The capability statements (the entire Chapter 6) are aligned with the domain-specific maturity scales and serve as an assessment instrument.

DR 3: The assessment methodology (Section 7.4) provides functional specifications for an output report based on each individual service. This report draws upon guidelines which are derived from the capability statements as well as the maturity assessment for a specific service.

DR 4: As part of the iterative design process, earlier versions of the TMSMM were used as part of telemedicine workshops, involving various role players from various health systems (Section 5.1.2), which demonstrates the value of the TMSMM to educate.

The maturity scale of the TMSMM is based on the maturity scale of the family of CMMs (Section 5.5). The third level of this five-level scale is labelled *defined* as it represents the standard for that particular capability area. The fourth level outlines standard quantitative management practices.

DR 5: After a few iterations it became evident that in many cases two capability statements are defined per maturity level per capability area. It was decided to pursue this as a design principle (Section 6.1.4). One of the motivations for doing this is that it contributed to the simplicity of the TMSMM and hence the ease of use.

The assessment methodology (Section 7.3) includes functional specifications for the capturing of assessment data, directed towards intuitive use. This includes input masks for the description of services as well as the concatenation of descriptions and capability statements to create service specific full sentence capability statements.

DR 6: The participants of the telemedicine workshops in which earlier versions of the TMSMM were used, were from various disciplines (Section 5.1.2). Also, linked to the previous design requirement, the functional specification for the description and assessment of the telemedicine service aims to provide an interface, which is accessible to role players from multiple disciplines.

DR 7: Exactly two capability statements are defined per level per capability area (Section 6.1.4). The uniformity of these scales makes it possible to aggregate the assessment of a cohort service along the domain dimension, the services dimension, the maturity scale or any combination of these. The assessment methodology describes the data warehouse structure and OLAP procedures to accomplish this (Section 7.5).

DR 8: Capability statements were deliberately formulated in such a way that they are not tied to any standards, technologies or concrete implementation details (Chapter 6). Appendices F and F.1 show all of the capability statements from different views. From neither view are any standards, technologies or concrete implementation details visible.

DR 9: Capability statements were deliberately formulated in such a way that they are mutually exclusive. The capability statements are viewed from different angles: In Chapter 6, statements are listed per capability area. In Appendix F.1 capability statements are viewed per type of service and in Appendix F.2 it is viewed per maturity level. From all of these views, the capability statements are mutually exclusive.

DR 10: To ensure collective exhaustiveness all frameworks from the state of the art, presented in Chapter 4, as well as other sources from the state of the art (Chapter 2) were considered when the capability statements were defined. Furthermore, feedback from telemedicine workshops, for which earlier versions of the TMSMM were used, were considered in follow-up iterations to ensure that all issues impacting on the maturity of telemedicine services are considered (Section 5.1.2).

DR 11: The capability statements are directly derived from the domain-specific maturity scales (Section 6.8). The relation between the capability statements and maturity levels can be seen if the capability statements are viewed per maturity level (refer to Appendix F.2).

DR 12: All domain-specific maturity scales are based on the maturity scale of the family of CMMs (Section 6.8). Each level of this scale implies previous scales. Capability statements were deliberately formulated in such a way that they accumulate. The accumulation of capability statements can be seen if the capability statements are viewed per capability area, as in Chapter 6.

8.3 Case Studies

Chapter 7 describes the methodology to describe, assess and analyze an individual telemedicine service or a cohort of services. Reference is also made in that chapter to a computer-based tool that was developed for purposes of this study. This tool was used to describe and assess a total of 28 telemedicine services (refer to Table D.1 for a complete list of services). The detailed description and assessment of four of these services are also included in Appendix D.1.

8.3.1 Individual case studies

The description and assessment data for these services were gathered through three different processes:

Expert interview process: The first phase of each expert interview involved the definition and mapping of at least one telemedicine service. The purpose of this was firstly to familiarize the expert with the TMSMM, but secondly, a complete service description and assessment was produced through this process.

Maturity assessment of services in the Western Cape: The Western Cape Department of Health gave permission that some of their healthcare facilities can be visited to identify, define and assess telemedicine services at these facilities, by means of the TMSMM. The documents concerning the ethical approval for these visits can be found in Appendix B. This forms part of the post graduate study by Hartmann (2013), under supervision of Van Dyk.

International cases from Med-e-Tel conference: The electronic proceedings of the 2013 Med-e-Tel Conference in Luxembourg includes 200 papers. Of these 200 papers a few dozen reported on specific telemedicine services. In seven of these papers the telemedicine service was described in sufficient detail so that it could be defined by means of the TMSMM-tool. Authors of three of these seven services (Roesler *et al.*, 2013; Lamprinos *et al.*, 2013; Figueria *et al.*, 2013) were interviewed during the conference to confirm correct interpretation of the paper and to complete the maturity assessment. The data for these three services are added to the data warehouse.

The Health Research Ethics Committees of Stellenbosch University as well as the Western Cape Departement of Health approved the gathering of empirical inputs for purposes of these case studies (refer to Appendix B). To ensure the integrity of the research process, the descriptions and assessment of all services were facilitated by two persons only (Liezl van Dyk or André Hartmann). These facilitators executed the first four assessments together to ensure alignment of the processes followed by the respective facilitators..

In the section that follows, it is explained how DRs 1, 2, 5, 6, 8, 11 and 12 are verified by the individual cases.

DR 1:	The TMSMM can describe any healthcare service that is delivered over a distance (telemedicine service).
DR 2:	The TMSMM enables the assessment of the maturity of this service.
DR 3:	Based on each service assessment, further steps towards the achievement of the target maturity state are indicated..
DR 4:	The TMSMM can be used as basis for education and explaining standards.
DR 5:	The maturity assessment methodology can be followed easily and intuitively.
DR 6:	Role players from multiple disciplines can use the TMSMM to describe and assess the telemedicine service on the detail level they are dealing with it.
DR 7:	Results from a cohort of individual service descriptions and assessments can be aggregated along all dimensions to an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic level decision-makers.
DR 8:	The TMSMM is not directly tied to any standards, technologies or concrete implementation details.
DR 9:	The capability statements are mutually exclusive.
DR 10:	The capability statements are collectively exhaustive.
DR 11:	Descriptions of capability statements clearly relate to and discriminate between maturity levels.
DR 12:	The capability statements and maturity levels accumulate. Each level and statement also includes the preceding lower level statements.

DR 1: The 28 individual case studies (Appendix D.1) include services that vary in terms of telemedicine specialization, service complexity, geographical area, health system, roles of participants and implementation life cycle. Despite this variation, it was possible to describe all of these services with the TMSMM.

DR 2: Despite the above-mentioned service variation, it was possible to assess all of these services with the TMSMM.

DR 5: The 28 individual services included in this study were described and assessed by 13 persons with varying exposure to telemedicine services. All of these persons were able to follow the assessment methodology - with the help of a facilitator - without prior exposure to the TMSMM.

DR 6: The 13 persons who contributed to the description and assessment of the 28 services were from multiple disciplines (six medical doctors, four engineers/ICTechnologist, three project managers).

DR 8: The 28 individual services also varied in terms of the standards, technologies or implementation detail. The TMSMM was applicable to all of these.

DR 11: With the assessment of the individual services, it was experienced that capability statements clearly relate to and discriminate between maturity levels.

DR 12: With the assessment of the individual services, it was experienced that capability statements accumulate.

8.3.2 Cohort case studies

From this collection of 28 services, two cohorts of services were selected and analyzed according to the assessment methodology described in Section 7.5. Appendices D.2 and D.3 present results from two respective cohort studies and explain the significance thereof for different higher level decision-makers. The validity of these results are considered in Section 9.3.2. It is demonstrated that results from a cohort of individual service descriptions and assessments can be aggregated along all dimensions to an output that is suitable for interpretation by external stakeholders, researchers, service providers and higher level decision-makers (DR 7).

8.4 Expert Interviews

The purpose of these interviews was to ask persons with expertise concerning the implementation and optimization of telemedicine services, whether or not the TMSMM satisfies all the design requirements. Table 8.1 contains information concerning the interviews and interviewees. The interview date and place are indicated in the first column. In the second column, the expertise of each person is described to motivate why this person is qualified to provide an expert opinion.

Table 8.1: Expert interviews

Person (Date) *Place*	**Expertise**
Ms Saskia Nychens (5 March 2013) *Offices of Telemed-Africa, Midrand*	As operations manager of Telemed-Africa she is responsible for the execution and co-ordination of "needs assessments, implementation of ehealth projects, change management, support and maintenance and training". Telemed-Africa is based in Midrand, but is also involved (amongst others) in telemedicine projects in Limpopo.
Prof Hoffie Conradie (11 March 2013) *Ukwanda Rural Clinical School (RCS), Worcester*	At the RCS healthcare professionals are trained within the rural context. As director of this school, Prof Conradie's concern is the optimal use of resources, including ICTs, to enable the delivery of healthcare where distance is an issue.
Dr Jacques du Toit (14 March 2013) *Swellendam Hospital*	Dr du Toit is the CEO of health services in the Bredasdorp and Swellendam sub-districts. He has knowledge about the implementation of a number of telemedicine services within these districts and was involved in or responsible for the implementation of a few.
Ms Jill Fortuin (18 March 2013) *Gordon's Bay*	Until recently, Ms Fortuin was Director of Telemedicine and mHealth at the Medical Research Council of South Africa. From 1 March 2013, she is a full-time PhD student in Telemedicine at the University of Western Cape.
Dr Mike Blanckenberg (14 May 2013) *Stellenbosch University*	Dr Blanckenberg is an electronic engineer. A senior lecturer of the Biomedical Engineering Research Group at Stellenbosch University, he was involved in the development of a number of telemedicine technology solutions (Behaimanot, 2005; De Vos and Blanckenberg, 2007; Blanckenberg *et al.*, 2011; Scheffer *et al.*, 2012), amongst which the MRC telemedicine workstation.
Ms Gladys Joubert (27 May 2013) *Universitas Hospital, Bloemfontein*	Ms Joubert is the co-ordinator of telemedicine services at Universitas Hospital, Bloemfontein, since 2005. In this capacity she was involved and still is in the implementation and maintenance of many telemedicine services for the Free State Department of Health.

The interview questions (Table 8.2) are aligned with the design requirements. With the permission of each expert, each interview was voice-recorded. Together with notes that were made during the interview, these voice-recordings were consulted when the interview feedback was summarized (Appendix C).

Table 8.2: Interview Questions per design requirement

DR 1: The TMSMM can describe any healthcare service that is delivered over a distance (telemedicine service)	Can you think of any telemedicine service (healthcare service that is delivered over a distance) that cannot be described with the TMSMM?
DR 2: The TMSMM enables the assessment of the maturity of this service.	Can you think of any telemedicine service (healthcare service that is delivered over a distance) that cannot be assessed with the TMSMM?
DR 3: Based on each service assessment, further steps towards the achievement of the target maturity state are indicated..	Based on the description and assessment, advice is provided concerning further actions to be taken. Would this advice influence your decisions and planning?
DR 4: The TMSMM can be used as basis for education and explaining standards.	Do you think the TMSMM can be used to educate other role players and explain standards about telemedicine?
DR 5: The maturity assessment methodology can be followed easily and intuitively.	Will you be able to use the TMSMM on your own?
DR 6: Role players from multiple disciplines can use the TMSMM to describe and assess the telemedicine service on the detail level they are dealing with it.	Which persons/entities should be involved to the definition and assessment of a telemedicine service?
DR 7: Results from a cohort of individual service descriptions and assessments can be aggregated along all dimensions to an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic level decision-makers.	Telemedicine services are defined and assessed according to a uniform framework to allow the analysis of a cohort of studies. Who would be interested in this, if any?
DR 8: The TMSMM is not directly tied to any standards, technologies or concrete implementation details.	Does the TMSMM indicate anything about specific standards, specific technologies, concrete implementation detail?
DR 9: The capability statements are mutually exclusive.	Is any combination of the statements in the TMSMM repeating / contradicting each other?
DR 10: The capability statements are collectively exhaustive.	Does the TMSMM consider all issues that impact on the success of telemedicine services?
DR 11: Descriptions of capability statements clearly relate to and discriminate between maturity levels.	Did you understand what was meant with each capability statement and how it differed from the other statements?
DR 12: The capability statements and maturity levels accumulate. Each level and statement also includes the preceding lower level statements.	For each aspect that is described, 11 capability statements are provided to help determine the maturity level of that aspect. Does each capability statement implicitly include previously listed statements?

8.4.1 Interview protocol

1. The researcher explains what the research is about. The "Informed Consent Form" is read and signed (refer to Appendix B for an example of this form).
2. A few pre-assessment questions are asked.
   2.1. What is your experience with respect to the use and implementation of telemedicine services?
   2.2. Which telemedicine services are you involved with, either as participant or as developer?
   2.3. Do you use any standard framework or guideline to help with the implementation and optimization of telemedicine services?
3. One or more telemedicine service are selected which can be described and assessed by the expert.
4. The conceptual framework that was developed in Chapter 5 is used to explain the basic building blocks of the TMSMM.
5. Then the TMSMM interface is used to describe and assess the maturity of this service. This process is facilitated by the interviewer. In doing so, the expert is familiarized with the detailed maturity levels and capability statements of the TMSMM.
   5.1. Use the TMSMM-tool to describe the service
   5.2. Assess the maturity of the current service
6. Answer the questions shown in the third column of Table 8.2. This table shows how the interview questions align with the design requirements.

8.4.2 Interview results

There was general consensus amongst experts as far as most of the interview questions were concerned. For three of these questions the opinions of experts varied to such an extent that further discussion is needed in this section.

DR 11	Descriptions of capability statements clearly relate to and discriminate between maturity levels.	Did you understand what was meant with each capability statement and how it differed from the other statements?

All experts agreed on this. However, one person pointed out that he only had clarity about some of the statements, because of additional information provided by the by the facilitator as part of the facilitation process.

DR 5	The TMSMM uses a data capturing mechanism that is easy and intuitive for end users.	Will you be able to use the TMSMM on your own?

All of the experts hesitated when asked this question. In hindsight, this is rather an indication of a poorly formulated research question than an indication that this design requirement is not satisfied. All of the respondents agreed that the TMSMM is easy to use, if the process is facilitated by someone with knowledge about model.

As part of the assessment methodology outlined in the previous chapter (Section 7.2.2), it is recommended that at least one of the persons involved must know the design of the conceptual TMSMM and appreciate how the capability statements relate to the maturity level. This person can then fulfill the role of facilitator. In Chapter 10 future work is recommended in this regard.

DR 10	The capability statements are collectively exhaustive.	Does the TMSMM consider all issues that impact on the success of telemedicine services?

Four of the six experts agreed on this. A fifth expert indicated "political will" as a key determinant in the successful implementation of telemedicine services, which is not indicated in the TMSMM. A sixth expert emphasised that for real-time telemedicine to be successful, it is important that users on both sides of the service are available at the same time. Although neither of these two issues are explicitely adddressed by the capability statements, it can be accommodated in future versions of the TMSMM within the capability areas on *National Policies and Strategies* and *Patient or Healthcare Worker*.

8.4.3 Verification of design requirements

The expert responses with respect to each respective design requirement are summarized below:

DR 1 and 2: None of the six experts could identify a telemedicine service that cannot be described by and assessed with the TMSMM. Although this consensus does not exclude the possibility that DRs 1 and 2 are not satisfied, it is very unlikely that this is the case.

DR 3: Two experts confirmed this design requirement without hesitation. The other four respondents emphasized that experience and knowledge of the persons involved in the service should be considered together with the output of the TMSMM. They indicated that the value of the TMSMM is that it guide towards a structured and systematic approach to the optimization of telemedicine services.

DR 4: All experts agreed that the TMSMM can be used as basis for education and explaining standards.

DR 5: It is suggested in the maturity assessment methodology, that description and assessment of telemedicine services are facilitated by someone that knows the TMSMM (Section 7.2.2). The experts agreed that the assessment methodology is easy and intuitive to follow, as long as such a facilitator is available.

DR 6: All six experts listed persons from multiple disciplines when they were asked who they believed can be involved in the assessment and definition of telemedicine services. Furthermore, the participants of the telemedicine workshops in which earlier versions of the TMSMM were used, were from various disciplines and many were novices concerning telemedicine.

DR 7: All interviewed experts identified higher-level decision-makers that could base decisions on these results, for example regional health systems managers, policy makers, government and business consultants.

DR 8: The experts also confirmed that the TMSMM is not directly tied to any standards, technologies or concrete implementation details.

DR 9: According to all six of the experts, the capability statements are mutually exclusive.

DR 10: Most experts agreed that the capability statements are collectively exhaustive. Two experts did highlight two issues that were not explicitly addressed by any capability statements. These issues can be accommodated in future versions of the TMSMM without any changes to the conceptual TMSMM.

DR 11: This was also confirmed by all of the experts.

DR 12: This was also confirmed by all of the experts.

8.5 Summary of Cross-verification

The design requirements are listed in the first column of Table 8.3. Columns 2,3 and 4 each summarizes the conclusions concerning the verification of the TMSMM as it was made in earlier sections. The last column, address the question: "Is the design requirement satisfied?".

Table 8.3: Cross-verification of design requirements

DR	**Reference to Intentional Design** *Section 8.2*	**Case studies** *Section 8.3*	**Expert interviews** *Section 8.4*	**Conclusion** *Section 8.6*
1. The TMSMM can describe any healthcare service that is delivered over a distance.	Matrix that combines the domain dimension and service dimension (see 5.4) and used in assessment methodology (see 7.3).	28 Individual services	Confirmed	Yes
2. The TMSMM enables the assessment of the maturity of this service.	Domain-specific maturity scale (see 5.5); Capability statements for each capability area (see Chapter 6)	28 Individual services	Confirmed	Yes
3. Based on each service assessment, further steps towards the achievement of the target maturity state are indicated.	Reports on individual services (see 7.4)	28 Individual services	Confirmed	Yes
4. The TMSMM can be used as basis for education and explaining standards.	Earlier versions of TMSMM used at workshops (see 5.1.2); Standards per maturity levels (see 5.5)	n/a	Confirmed	Yes
5. The maturity assessment methodology can be followed easily and intuitively.	Standardize to two capability statements per capability area (see 6.1.4); Methodology to describe and assess each service (see 7.3)	28 Individual services	Confirmed, future work identified	Yes, assuming availability of facilitator

DR	**Reference to Intentional Design** *Section 8.2*	**Case Studies** *Section 8.3*	**Expert Interviews** *Section 8.4*	**Conclusion** *Section 8.6*
6. Role players from multiple disciplines can use the TMSMM to describe and assess the telemedicine service on the detail level they are dealing with it.	Earlier versions of TMSMM used at workshops (see 5.1.2); Functional specifications for the description and assessment of individual services (7.3)	28 Individual services	Confirmed	Yes
7. Results from a cohort of individual service assessments can be aggregated to an output that is suitable for interpretation by higher-level decision-makers.	Standardize to two capability statements per capability area (see 6.1.4); Aggregation into cohort case studies (see 7.5)	3 Cohort case studies	Confirmed	Yes
8. The TMSMM is not directly tied to any standards, technologies or concrete implementation details.	Formulation of capability statements (see 6.8), Capability statements viewed per *Domain* (see F) and per *Type of Process* (see F.1)	28 Individual services	Confirmed	Yes
9. The capability statements are mutually exclusive.	Capability statements viewed per *Domain* (see F) and per *Type of process* (see F.1)	n/a	Confirmed	Yes
10. The capability statements are collectively exhaustive.	All available telemedicine frameworks considered (see 6.8)	n/a	Confirmed	Future work identified.
11. Descriptions of capability statements clearly relate to and discriminate between maturity levels.	Domain-specific maturity scale (see 5.5 and 6.8), Capability statements viewed per *Maturity Level* (see F.2)	28 Individual services	Confirmed	Yes
12. The capability statements accumulate. Each level and statement also includes the preceding lower level statements.	Domain-specific maturity scale (see 5.5), Capability statements viewed per domain (see F) and per type of process (see F.1)	28 Individual services	Confirmed	Yes

8.6 Conclusion

The objective of this chapter was to confirm that all the DRs are satisfied by the TMSMM. This was done by means of a retrospective review of the design process, case studies and expert interviews. The conclusions from each of these methods are summarized in Table 8.3.

All design requirements were positively verified by two or three research methods. The verification processes for design requirements 5 and 10 indicated room for futher research and development:

DR 5: It is common practice with respect to many other maturity models that the assessment is facilitated by a person who is specifically trained for this purpose. A detailed procedure for the training of TMSMM facilitators should be part of the assessment methodology, especially as the model evolves from a descriptive to a prescriptive to a comparative model.

DR 10: It is naïve to claim collective exhaustiveness for any knowledge domain. Two issues were highlighted by experts that were not explicitly addressed by any of the capability statements and which should be included in future versions of the TMSMM, together with other issues that may surface as the TMSMM and the telemedicine knowledge domain evolves.

By confirming that the TMSMM satisfies all design requirements, Research Question 6 is answered. Because of the verification process, some areas for future work was identified and will be considered in the concluding chapter of this thesis. The next chapter considers the validity of the research process and the research outcome.

Chapter 9

Validation

The Latin root of the word *validation* is *valere*, which literally means *weight*. *Valere* is also the root of the word *value*. This chapter contemplates the rigor (*weight*) of the research process as well as the *value* of this study to the world beyond the research context.

9.1 Validation Methodology

Figure 9.1 indicates the sequence, the controls (downwards arrows) and the inputs (upwards arrows) of the research process. Chapter 9 focusses on internal and external validation. The purpose of internal validation is to ensure that the research process contains sufficient controls to ensure that the research outputs are warranted by the research inputs. With external validation it must be shown that the research outputs can be used to make generalizations about the world beyond the research context (Leedy and Ormrod, 2012).

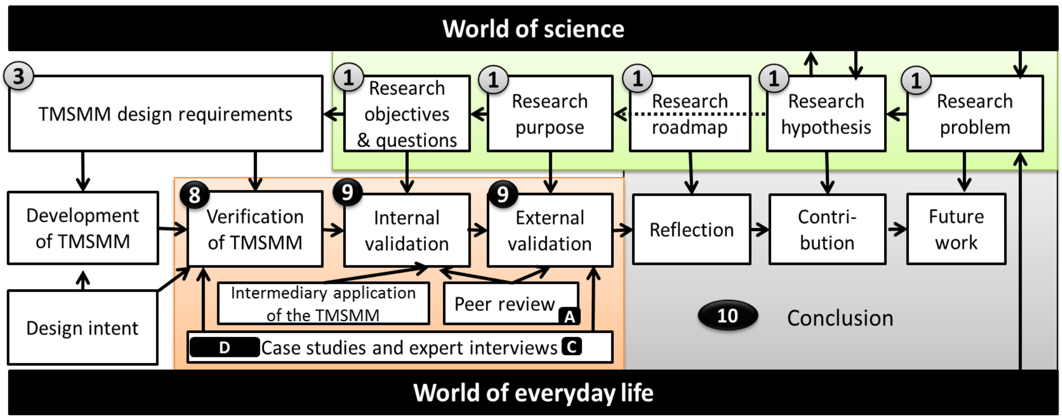

Figure 9.1: Research roadmap: Verification, validation and conclusion

Research Question 7.1 (Internal validation): Are the answers to each research question warranted by the research inputs and research process? In Section 9.2 retrospective review of the research process, intermediary applications of the TMSMM and expert interviews are used to confirm that the answers to the research questions are warranted by the intputs.

Research Question 7.2 (External validation): Is the research purpose accomplished with respect to the world beyond the research context? Section 9.3 draws upon expert interviews, cohort case studies and peer review to confirm that the research purpose is accomplished and can be generalized with respect to the world outside the research context.

9.2 Internal Validation

Internal validation is firstly done by means of a retrospective review of the research process. Secondly it is explained how intermediary applications of the TMSMM were used as input to the research process. Thirdly, several academic peer review processes are described which are directed to a certain (set of) research question(s). All peer reviewed publications, including studies concerning the application of earlier versions of the TMSMM, are included in Appendix A. This section is concluded by a cross verification, which includes all of these methods, to confirm that all research questions are answered.

9.2.1 Retrospective review of research process

This section is a retrospective review of this research process, to argue that the research questions were indeed addressed.

RQ 1.1, RQ 1.2: Concepts, approaches and paradigms relevant to this study, were taken from the work of respected researchers. Academic research articles, white papers and other sources of grey literature were consulted, together with interaction at several domain-specific conferences. The literature study which is presented in Chapter 2 covers only the core of the state of the art, as deemed necessary for purposes of this study. In cases where insufficient consensus existed amongst researchers, definitions were formulated for purposes of this study.

RQ 1.3: A statistical topic analysis (STA) of 1772 academic articles, together with Gartner's telemedicine Hype Cycle and Google search trends was used to identify and discuss the most frequently used telemedicine specializations (Section 2.3.1).

RQ 2.1: After the early 1980s maturity models became popular in the world of everyday life as instruments to manage, standardize, measure and optimize processes in complex systems. It is only recently that researchers have started to consider the science of maturity models (Fraser *et al.*, 2002; De Bruin *et al.*, 2005; Jokela *et al.*, 2006; Kohlegger *et al.*, 2009; Niehaves *et al.*, 2011; Mettler, 2011; Pöppelbuß *et al.*, 2011; Pöppelbuß and Röglinger, 2011; Maier *et al.*, 2012).

These authors conducted meta-studies, i.e. they considered a certain collection of maturity models in order to create generalizable descriptions, models and theories. These publications were also cited by numerous other authors, which confirms the validity thereof. Concepts, approaches and paradigms relevant to this study, were taken from the work of these authors and presented in Chapter 3. In cases where insufficient consensus existed amongst researchers, definitions were formulated for purposes of this study. Design requirements for a maturity model for telemedicine services were defined accordingly.

RQ 2.2: It was found in the state of the art that maturity models are most often developed by means of an iterative design process (Section 3.5.1). This process can either be a so-called bottom-up process or top-down process. In a bottom-up approach capabilities are defined first and then, based on these definitions, maturity levels are defined and the rest of the maturity model is constructed.

RQ 1.1:	What is the origin of telemedicine? What are the existing definitions, paradigms and trends?
RQ 1.2:	What are the existing definitions, paradigms and trends concerning telemedicine?
RQ 1.3:	What are typical telemedicine services?
RQ 2.1:	What are the existing definitions, paradigms and trends concerning the science of maturity models?
RQ 2.2:	Which design considerations are applicable to maturity models?
RQ 3:	What are the design requirements a reference model must satisfy so that it can be used to assess telemedicine services and to guide and educate stakeholders towards the optimization of these services?
RQ 4.1:	Which telemedicine reference models, frameworks or guidelines exist?
RQ 4.2:	Which design requirements are satisfied by each of the respective frameworks?
RQ 4.3:	Do any of these frameworks satisfy all the design requirements?
RQ 5.1:	What conceptual design will address the design requirements?
RQ 5.2:	Which detail descriptions in terms of capability statements will address the design requirements?
RQ 5.3:	Which assessment methodology will address the design requirements?

RQ 3: There does not exist an "off-the-shelf" list of design requirements for a typical maturity model. Design considerations for maturity models were identified from the state of the art and twelve design requirements applicable to the purpose of this study were formulated in Section 3.6.

RQ 4.1: Many frameworks were developed during the past two decades with the purpose of understanding and managing telemedicine services. Futhermore, a few maturity models were identified that are directed towards certain healthcare systems or services. A number of these frameworks were selected in Chapter 4 based on their authority, in terms of references by other researchers, as well as their potential to address the research problem.

RQ 4.2: The design requirements form a golden thread that is woven hrough the entire study. In Chapter 4 the existing telemedicine frameworks were evaluated in terms of these design requirements.

RQ 4.3 The results of this evaluation is summarized in Section 4.8 by means of a requirements map. The conclusion that can be made from this is that none of these frameworks satisfy all of the design requirements.

RQ 5.1, RQ 5.2, RQ 5.3: The TMSMM was developed by means of a top-down iterative design process. Firstly, the conceptual model was developed in Chapter 5, using inputs from stakeholder workshops (world of everyday life as well as knowledge from the world of science). Thereafter, the capability statements were formulated (Chapter 6) within the frame provided by the TMSMM. Finally a maturity assessment methodology is defined (Chapter 7) according to which the TMSMM can be used to describe and assess telemedicine services and to aggregate and analyze the captured data. The retrospective review of the design process (Section 8.2) indicates how each of these design requirements was addressed in these respective chapters.

9.2.2 Intermediary case studies of the TMSMM

The iterative design process included inputs from telemedicine practitioners as well as the application of telemedicine services to earlier versions of the TMSMM (the world of everyday life). These applications are not formally documented, but it is part of the work by Van Dyk *et al.* (2012*b*); Van Zyl (2012) and Viljoen (In process).

The paper by Van Dyk *et al.* (2012*b*) includes three case studies of telemedicine services. These services were documented and assessed by both the TMMM (Telemedicine Maturity Model, as it was called at that stage) and the roadmap of the Centre of eHealth Research (CeHReS), University for Twente (Netherlands). The three cases include a South African PACS-centered teleradiology service, a South African mobile phone-driven teledermatology service and a European web-based platform for infection management. Two different assessments were done with respect to the web-based platform. First the service was assessed during development phase and, secondly, in operational phase. The purpose of this paper was to compare these two frameworks with each other and to propose a combined framework which draws upon the strengths of both frameworks.

Van Zyl (2012) conducted a meta-study for purposes of an MEng-study under supervision of Van Dyk. They used an earlier version of the TMSMM to describe a selection of telemedicine services that were published in the *Journal for Telemedicine and Telecare* between 2006 and 2011. The number of services of each type included in this study are indicated by Figure 9.2. All of these articles had sufficient information to describe each service, but it did not provide appropriate information to allow assessments. Van Zyl (2012) aggregated these data to get an overview of the type of telemedicine services as well as the typical users, devices and methods used for each.

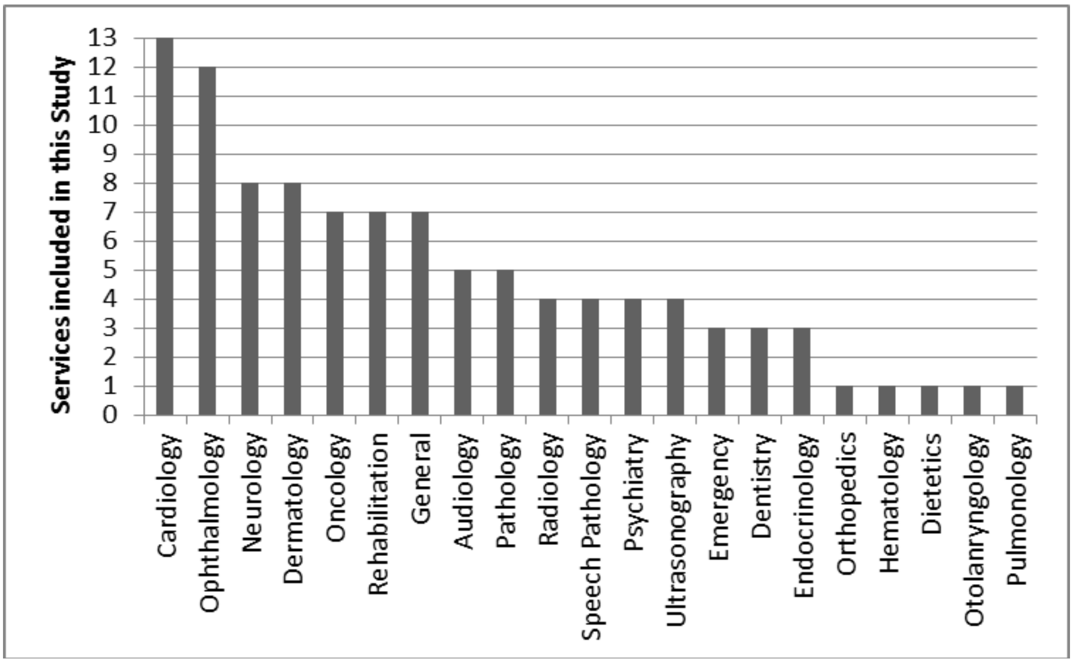

Figure 9.2: Telemedicine services included in the meta-study by Van Zyl (2012)

Viljoen (In process) is using the TMSMM as basis to develop an mhealth services assessment tool, which is used by the health directorate of the GMSA (*Groupe Speciale Mobile Association*) to assess their mhealth projects in low to medium income (LMIC) countries. The first iterations in the development of this tool involved the use of the TMSMM to describe and assess a selection of mhealth services. At that stage, the capability statements of the TMSMM were not yet finalized. The application of the TMSMM to these services either confirmed that the conceptual model and capability statements adhere to all DRs or it highlighted areas for improvement. The formulation and organization of certain capability statements were updated accordingly.

RQ 1.3: Many telemedicine specializations and applications are represented by the services described above. It contributes to an understanding of the typical TMSMM and also confirmed that the TMSMM can be applied to any telemedicine service.

RQ 5.1: The studies by Van Dyk *et al.* (2012*b*) and Van Zyl (2012) were executed during the conceptual TMSMM development phase. These studies served as confirmation that the design requirements are satisfied and it also provided direction for improvements during further development iterations.

RQ 5.2: The study by Viljoen (In process) was executed after finalization of the conceptual TMSMM and during the capability statement development phase. It served as confirmation that the capability statements are indeed generic statements that describe the characteristics of processes as it applies to a specific maturity level and it also provided direction for improvements concerning the formulation of capability statements.

RQ 5.3: The assessment methodology (Chapter 7) describes how the telemedicine services should be described and assessed, but also how the individual reports should be generated and how the data should be organized, aggregated and analyzed for purposes of cohort case studies. The intermediary application of the TMSMM provided data to test, refine the assessment methodology and to show that research outputs are warranted by the research inputs.

9.2.3 Academic peer review

> Academic peer review is the process of engaging substantive experts to read and comment on new research in the fields in which they study in order to validate and certify that research. Peer review is an essential dividing line for judging what is scientific and what is speculation. (Elsevier, 2013)

A number of research outputs were produced along the research process. These research outputs were subjected to academic peer review, which serve as further validation of the research outputs. Each of these research outputs is directed to a certain (set of) research question(s) as indicated in this section.

Table 9.1: Research outputs: Understanding the telemedicine landscape

Title	In-text reference	Type of Output	Audience	App.
Towards a Regional Innovation System for Telemedicine in South Africa	Van Dyk *et al.* (2010)	International conference paper	eHealth practitioners and researchers	A.1.1
Telemedicine - Leverage Competitive Advantage through the use of ICT Investment	Van Dyk (2010)	Local conference paper	Industrial Engineers	A.2.1
A framework for the assessment of teleradiology in South Africa: An Eastern Cape Case Study	Haumann *et al.* (2011)	International conference paper	ehealth practitioners and researchers	A.3.1
A telemedicine system to increase patients' access to specialised cardiac care for assisting remote diagnosis	Triegaardt *et al.* (2011)	International conference paper	eHealth practitioners and researchers	A.3.2
A health systems engineering approach to meeting the demand for skilled foetal ultrasound services in the Boland/Overberg public health district	Uys and Van Dyk (2011)	International conference paper	eHealth practitioners and researchers	A.3.3
A National Telemedicine Survey	Fortuin and Van Dyk (2011)	International conference paper	eHealth practitioners and researchers	A.3.4
Clinical-pull approach to telemedicine implementation policies using health informatics in the developing world	Treurnicht and Van Dyk (2012)	Book Chapter	eHealth practitioners and researchers	A.4.1

RQ 1.1, RQ 1.2: The papers listed in Table 9.1 were produced at the beginning of this study and contributed to the exploration of the state of the art as well as the conceptualization and validation of the research problem.

RQ 1.3 Appendices A.3.1 A.3.3, A.3.2 are studies about specific telemedicine specializations. The Statistical Topic Analysis of 1772 academic articles on telemedicine can be found in Appendix A.2.1. This paper was published in the early stages of this study as a way to explore the state of the art. The vocabulary created by this analysis was later used in Section 2.3.1.

RQ 2.1, RQ 2.2, RQ 3: During the conceptual TMSMM development phase, feedback was obtained from one of the one of the scholars on the science of maturity models, cited in Chapter 3. Kohlegger (2012) evaluated earlier versions of the TMSMM and provided valuable feedback and advice concerning the development of this maturity model.

RQ 4.1: The research outputs listed in Table 9.2 relate to some of the frameworks presented in Chapter 4, for example the *eHealth Readiness Assessment Tools* of Khoja *et al.* (2007) were administered amongst persons from the national and provincial DoHs of South Africa.

Table 9.2: Research outputs: Telemedicine frameworks

Title	**In-text reference**	**Type of Output**	**Audience**	**App.**
eHealth Assessment Survey Amongst Members of the South African Department of Health (DoH)	Van Dyk and Fortuin (2011)	Local conference presentation	ehealth practitioners and researchers	A.6.1
Business Models for Sustained eHealth Implementation: Lessons from Two Continents	Van Dyk *et al.* (2012*b*)	International conference paper	Industrial Engineers	A.2.3
Assessing the Technology Acceptance of Cell Phones within the Context of the Primary Health Care System	Snyders and Van Dyk (2013)	Local conference paper	Industrial Engineers	A.2.5

RQ 5.1, RQ 5.2: The first three research outputs listed in Table 9.3 each marks the completion of an iteration in the development of the conceptual TMSMM. The fourth output also includes capability statements.

Table 9.3: Research outputs: Development of the TMSMM

Title	**In-text reference**	**Type of Output**	**Audience**	**App.**
A Systems Engineering Approach to Telemedicine System Implementation	Van Dyk *et al.* (2011)	Local conference paper	Industrial and Systems Engineers	A.2.2
A Maturity Model for Telemedicine Implementation	Van Dyk *et al.* (2012*a*)	International conference paper	ehealth practitioners and researchers	A.1.2
Development of a Maturity Model for Telemedicine	Van Dyk and Schutte (2012)	Full Journal Article	Industrial Engineers (SA Context)	A.5
The Telemedicine Maturity Model: A generic tool for the measurement and improvement of telemedicine services	Van Dyk and Schutte (2013)	Chapter in Book		A.4.2

9.3 External Validation

Research Question 8 (External validation): Is the research purpose accomplished with respect to the world beyond the research context?

The purpose of the external validation is to determine if the TMSMM can be used to make generalizations about the world outside the research context. The purpose of this study is to either find or develop a maturity model for telemedicine services that can be used to describe and assess telemedicine services and to guide and educate stakeholders towards the optimization of these services.

The ideal research method for external validation of the TMSMM is to apply the TMSMM to a large enough sample of telemedicine services, sustain these applications for a few months or years and then to evaluate if the TMSMM indeed contributed to the optimization of the telemedicine services. Unfortunately, this method is not feasible within the timeframe of a doctorate study. Due this limitation is not possible to prove that the research purpose is accomplished with respect to all cases beyond the research context. In this section, three other research methods are applied which collectively confirm the applicability of the TMSMM to some situations beyond the research context.

Expert opinions were used in the previous chapter to confirm that all design requirements are met. The same experts also gave their opinion on the applicability of the TMSMM in their particular context. Section 9.3.1 considers whether these opinions indeed confirm that the research purpose is accomplished with respect to the world beyond the research context.

The cohort case studies of Section 9.3.2 demonstrate how the TMSMM are used to produce research outputs of value to the world beyond the research context.

Academic peer review on the most recent research outputs also provides external validation, as is explained in Section 9.3.3

9.3.1 Expert opinions

The responses from expert interviews, which are documented in Appendix C, were summarized in Chapter 8 to verify that the TMSMM does adhere to the design requirements. Four of the design requirements and expert questions listed in Table 9.4 are focussed on the world beyond the research context.

With the exception of one expert, none could imagine any telemedicine service that cannot be described and assessed with the TMSMM. The sixth expert was initially concerned that the TMSMM cannot be applied to real-time telemedicine services.

Table 9.4: External validation: Questions from expert interview

	Design requirement	Interview question
DR 1 and DR 2	The TMSMM can describe any healthcare service that is delivered over a distance.	Can you think of any telemedicine service (healthcare service that is delivered over a distance) that cannot be described and assessed with the TMSMM?
DR 4	The TMSMM can be used as basis for education and explaining standards.	Do you think the TMSMM can be used to educate other role players and explain standards about telemedicine?
DR 7	Results from a cohort of individual service assessments can be aggregated to an output that is suitable for interpretation by higher-level decision-makers.	Telemedicine services are defined and assessed according to a uniform framework to allow the analysis of a cohort of studies. Who would be interested in this, if any?
DR 8	The TMSMM is not directly tied to any standards, technologies or concrete implementation details.	Does the TMSMM indicate anything about specific standards, specific technologies, concrete implementation detail?

However, after some contemplation he realized that a real-time telemedicine service can be broken down into the same basic processes and assessed accordingly. One of the experts admitted that he is not involved in the training and education of users and therefore preferred not to comment on the second question of Table 9.4. All the others agreed that the TMSMM can be used within their respective contexts for purposes of education and the explaination of standards.

Within the scope of each expert interview, it was not possible to present experts with results of a cohort analysis of cases. However, all experts did appreciate the potential of the TMSMM to produce aggregated results. They furthermore identified various decision-makers that should be interested in these results, for example health district managers, local and national policy makers, telemedicine co-ordinators, business consultants and researchers.

All the experts agreed that the TMSMM is not directly tied to any standards, technologies or concrete implementation details. Three of these experts specifically observed that this characteristic of the TMSMM contributes to its generalizability.

9.3.2 Cohort case studies

These cohorts were decided upon after the data for all 28 services was collected. The following criteria were used to decide on the services for the cohort studies:

- Each cohort must represent at least 25 per cent of the services.
- Each cohort must have a unique set of stakeholders that may be interested in this study.

It is important to note that the purpose of these cohort studies is only to demonstrate that the TMSMM can be used to make generalizations about the world outside the research context. As part of future work (Section 10.4) studies are anticipated that use the TMSMM to gather data from a larger and more representative sample of service cohorts in order to produce actual generalizable results.

The two cohort studies and the stakeholders that may be interested in this study, are as follows:

Appendix D.2: All teleradiology services from the list of 28 services included in this study, irrespective of technology driver or healthcare institution. External stakeholders that may be interested in this cohort study are radiologists and radiographers that make use of teleradiology or who are interested in doing so; providers of teleradiology technology and infrastructure, for example SITA (State Information Technology Agency); telemedicine co-ordinators responsible for the implementation of telemedicine services within a specific context as well as high-level policy makers.

Appendix D.3: All telemedicine services at a specific hospital network, irrespective of specialization or technology driver. The target external audience for this cohort study is typically hospital superintendents and regional managers and telemedicine co-ordinators.

More cohort studies can be executed, depending on the quantity and nature of individual telemedicine services described and assessed, as well as the type of management information required. In the sections that follow, findings from each of these cohort studies are shared in order to demonstrate that generalizations can be made about the world outside the research context.

9.3.2.1 Teleradiology case study

In South Africa most private hospital groups and some public hospital networks have fully functional teleradiological services. Within the private health sector the PACSs are fully integrated with the hospital information system as well as information systems from medical insurers. In some areas of the South African public health sector, teleradiology services run successfully on a PACS. At other places less sophisticated teleradiology services are found, for example:

- "Hard-copy" radiological images (e.g. x-rays) are taken and then digitized by means of a scanner, from where it is uploaded to a PACS.
- "Hard-copy" radiological images (e.g. x-rays) are taken and then digitized by means of a scanner, from where it is e-mailed to specialist. The image is not archived.

- Medical officers take digital pictures of the "hard-copy" radiological image and SMS this image to specialist.

Can the analyses in Appendix D.2 indeed be used to assess teleradiology services as cohort and to guide and educate stakeholders towards the optimization thereof? The possible value of a case study like this for each of these stakeholders is summarized below.

Providers of Teleradiology Technology and Infrastructure: Research on telemedicine most often focusses on cutting technology and best practices or, on the other hand, on service failures and possible reasons for these. Cohort studies like these provide a simple inventory of current technology and practices, which is otherwise not known.

Telemedicine co-ordinator (Person responsible for the planning and implementation of telemedicine services for a certain system, e.g. group of hospitals): The maturity of the users (*man*) has the greatest variation amongst different services. A deliberate effort is necessary to educate and motivate all users concerning the teleradiology services.

Policy makers on provincial and governmental level: These stakeholders should take note of the fact that in the case of services that originated from a bottom-up initiative by healthcare workers, the cost incurred by the healthcare worker has most often not been considered.

Radiologists and Radiographers: Generally, the same medical protocols apply to the capturing and diagnosing process as would have been the case if the service was not delivered over a distance.

9.3.2.2 Hospital network cohort study

For purposes of this cohort study a hospital network is considered to be a tertiary or secondary hospital, which is connected to a few clinics. This is also referred to as *hub-and-spoke*. Amongst the 28 telemedicine services listed in Appendix D.1 are 24 services from a total of nine such hospital networks.

Seven of these 24 services belongs to *Hospital Network C*. Appendix D.3 shows the data aggregation and analysis for these seven services. The possible value of a case study like this for each of these stakeholders is summarized below.

Telemedicine co-ordinator of the specific hospital network:

Managers (overall, clinical and technical) at the central hospital as well as secondary hospitals and healthcare clinics within the network: When a new telemedicine service is planned, it is good to consider the levels of maturity at the hospital and clinics that will be part of this new service.

Potential sponsors of pilot projects: Companies, for example mobile phone service providers, often sponsor telemedicine experiments and pilot projects.

Telemedicine co-ordinators of other hospital networks may be interested in similar analysis for benchmarking purposes.

Decision-makers at provincial and governmental level: Figure D.28 shows the roll-up view of average maturity per hospital network. Decision-makers can identify hospital networks with high maturity in certain capability areas with the purpose of identifying best practices. This figure also indicates areas in terms of hospital complex, but also capability areas that need particular attention.

9.3.3 Peer review

The final three research outputs (Table 9.5) serve as further external validation. Van Zyl (2012) (under supervision of Van Dyk) applied an earlier version of the TMSMM to 102 articles from the *International Journal for Telemedicine and Telecare*. The paper by Hartmann and Van Dyk (2013) is part of another MEng study which is executed under supervision of Van Dyk.

Table 9.5: Research outputs: External validation

Title	**In-text reference**	**Type of Output**	**Audience**	**App.**
A Meta-Study of 102 Telemedicine Services from the *International Journal for Telemedicine and Telecare*	Van Zyl (2012)	Chapter in M Eng Thesis (Supervisor)	Industrial Engineers	A.6.2
A Staged Telemedicine Reference Tool for Optimization of Telemedicine Services	Van Dyk (2013)	International conference presentation	ehealth practitioners and researchers	A.3.6
An Assessment of the Maturity of Teleradiology Services within the South African Public Healthcare System	Hartmann and Van Dyk (2013)	Local conference paper	Industrial Engineers	A.2.4

The TMSMM was presented to an international audience at the annual Med-e-Tel Conference (The International eHealth, Telemedicine and Health ICT Forum) in Luxembourg, April 2013. The comments that were received on this presentation indicate that the TMSMM is also valid outside the South African context):

- A head of a medical informatics unit at a university in the USA that a reference model, like this, is much needed. It provides a practical tool to get a holistic view and cross-implementation view on telemedicine services.
- A business analyst from a European mobile phone operator realized the potential use of TMSMM as business analyses tool for mobile operators and other service providers.
- The author of two individual cases included in the case study data warehouse confirmed the value of the TMSMM as a way of systematically and continuously following the progress of the telemedicine service.

Table 9.6 summarizes the conclusions concerning the question whether the research purpose is accomplished with respect to the world beyond the research context.

Table 9.6: External validation: Cross-validation of research purpose

Expert opinions *Section 9.3.1*	**Cohort case studies** *Section 9.3.2*	**Peer review** *Section 9.3.3*
Agreement that the TMSMM can be applied to any telemedicine service and aggregated for decision making by an external target audience.	Two cohort case studies demonstrated that results obtained by the TMSMM can be generalized to the world beyond the research context.	Three peer reviewed research outputs that were produced after finalization of the TMSMM confirms the external validity.

Table 9.7 summarizes the findings concerning the internal validity of the research process. The research questions are listed in the first column. The second, third and fourth columns indicate the findings from Sections 9.2.1, 9.2.2 and 9.2.3 respectively.

9.4 Conclusion

The Latin root of the word *validation* is *valere*, which literally means *weight*. In this chapter the internal validity of the research process was considered by *weigh*ing it up against the research outputs. This was done by means of a retrospective review of the research process, intermediary case studies as well as academic peer review. *Valere* is also the root of the word *value*. The external value of the TMSMM to the world beyond the research context was evaluated by means of expert opinions, cohort case studies, as well as peer review. By doing this, the internal and external validity of the research process was confirmed. This study is concluded in the next chapter.

Table 9.7: Cross-validation of research questions

Research question	**Research process** *Section 9.2.1*	**Intermediary cases** *Section 9.2.2*	**Peer review** *Section 9.2.3*	**Valid answer to research question?**
1.1. What is the origin of telemedicine? What are the existing definitions, paradigms and trends?	Chapter 2		Table 9.1	Yes
1.2. What are the existing definitions, paradigms and trends concerning telemedicine?	Chapter 2		Table 9.1	Yes
1.3. What are typical telemedicine services?	Section 2.3.1	Examples across speciali-zations	Appendices A.3.1, A.3.2, A.3.3	Yes
2.1. What are the existing definitions, paradigms and trends concerning the science of maturity models?	Chapter 3			Yes
2.2. Which design considerations are applicable to maturity models?	Section 3.5.1			Yes
3. What are the design requirements a reference model must satisfy so that it can fulfill the research purpose?	Section 3.6			Yes
4.1. Which telemedicine reference models, frameworks or guidelines exist?	Chapter 4		Table 9.2	Yes
4.2 Which design requirements are satisfied by each of the respective frameworks?	Chapter 4			Yes
4.3 Do any of these frameworks satisfy all the design requirements?	Section 4.8			Yes
5.1. What conceptual design will address the design requirements?	Chapter 5 and Section 8.2	Iterative design of the conceptual TMSMM	Table 9.3 to A.4.2	Yes
5.2. Which detail descriptions in terms of capability statements will address the design requirements?	Chapter 6 and Section 8.2	Refine and validate capability statements	Table 9.3	Yes
5.3. Which assessment methodology will address the design requirements?	Chapter 7 and Section 8.2	Intermediary cases provided test data		Yes

Chapter 10

Conclusion

To *conclude* one's *research* may seem like a contradiction in terms. This is because the word research suggests an ongoing process of discovery while conclusion indicates an ending. This chapter should thus be considered as merely a snapshot in the process of the search for knowledge, models and theories concerning the maturity of telemedicine services. The following four sets of questions may be helpful in contextualising this snapshot.

Reflection: Where were we? How did we get here? (Section 10.1)

Limitations: Where did we want to be? What limited us in getting there? (Section 10.2)

Contribution: Where are we? What was achieved? (Section 10.3)

Future Work: Where do we want to be? What are the next steps to take? (Section 10.4)

10.1 Reflection

Where were we? How did we get here?

Figure 10.1 shows the map of the completed research. The research journey, as it was documented in Chapters 1 to 10, is indicated by the alphabetically labelled squares. The alignment between the first chapter and this one is also indicated in this diagram.

The research problem [A] originated from the world of everyday life as well as the world of science. Practicalities in everyday life showed that despite the potential contribution of telemedicine to the quality and accessibility of healthcare, the success rate has been disappointing. Many mistakes in the implementation of telemedicine services have been repeated over and over again with only a few

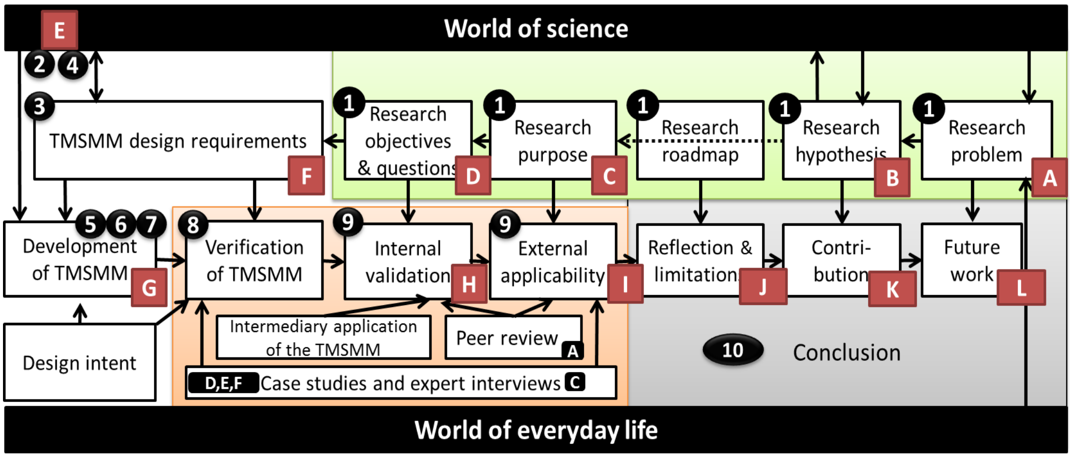

Figure 10.1: Complete research roadmap

examples of good practice being replicated. This lead to a search for scientific models and frameworks that could be used, both to assess telemedicine services, as well as to guide and educate stakeholders. However, these frameworks have been found to be unsatisfactory for this purpose.

Maturity models were found in the world of science and their potential to address the research problem was recognized. The research hypothesis [B] and purpose [C] and research objectives [D] were defined accordingly.

The purpose of this study was to find a maturity model for telemedicine services that can be used both to describe and assess telemedicine services and to guide and educate stakeholders towards its optimization.

In Chapters 2 and 3 the state of the art (world of science) was considered in order to draw the telemedicine landscape and also to understand the science of development maturity models [E]. Design requirements for a maturity model for telemedicine services were defined accordingly [F]. These requirements were used as criteria to determine if any of the existing telemedicine frameworks or maturity models within a health system context can fulfill the purpose of a maturity model for telemedicine services. No such framework was found. Hence, a new TMSMM had to be developed [G]. Chapters 5,6 and 7 give a full explanation of this process.

These research objectives and questions [D] formed the backbone of the study and also the basis for the investigation into the internal validity [H] of the study, which was discussed in the first part of Chapter 9. The second part of Chapter 9 provides evidence that the TMSMM can be applied to the world outside the research context.

This chapter looks back on the research journey and the next section [J] describes the limitations of this study. The unique research contribution made by this study

[K] was expressed in Chapter 1 in the form of the research hypothesis and is revisited in the section 10.3. Thereafter, future work [L] are contemplated in Section 10.4.

10.2 Limitations

Where did we want to be? What limited us in getting there?

The research laboratory of an enterprise engineer comprises of one or more enterprise. In the case of this study, these enterprises are in the form of telemedicine services. In contrast with most other engineering researchers, enterprise engineers do not have much control over their laboratory. In additiona, the lead time of experiments within this laboratory normally exceeds the timeframe of a typical research project. Another constraint is that there are generally fewer samples of enterprises available in an enterprise engineer's laboratory than in other engineering laboratories.

The same challenges limited this study:

- The ideal research method for external validation of the TMSMM is to apply the TMSMM to a sufficiently large sample of telemedicine services, sustain these applications for a few months or years while continuously monitoring the effects of the TMSMM on the service. It would then be necessary to evaluate whether the TMSMM had indeed contributed to the optimization of the telemedicine services. However, the time taken to conduct these experiments would exceed the timeframe allowed for a typical doctoral study.
- Ideally, for the purposes of validation, it is important that the sample of services that are covered is representative of the full range of telemedicine services. However, in this study, these services were selected based on availability and accessibility, rather than representation.

10.3 Contribution

Where are we? What was achieved?

The research journey fluctuated between the world of everyday life and the world of science.

10.3.1 The world of science

This study, first, contributed to the theories and models by means of a thorough review and synthesis of existing frameworks and models. Secondly, new a maturity model was developed specifically as reference model for telemedicine services. Many models exist that can be used to assess a telemedicine service. Some models provide guidelines for the implementation of telemedicine services, others allow assessment of processes and guide accordingly towards a desired state of maturity, but are not specifically applicable to telemedicine services. The major contribution of this study is therefore a TMSMM that can be used as reference model for the assessment and maturation of telemedicine services.

The TMSMM was developed by means of continuous interaction between the realm of everyday life and the world of science. The plural of the word *world* is deliberately used here: the development, implementation and optimization of telemedicine services require services require extensive multidisciplinary efforts involving clinicians, medical specialists, technicians, managers, technical engineers, enterprise engineers, (health) economists, et cetera. The multidisciplinary nature of the telemedicine domain is possibly one of the greatest challenges concerning the development, implementation and optimization of telemedicine services. No single roleplayer has all the knowledge and skills to address the research problem.

Even more challenging than developing telemedicine services is conducting research within this multidisciplinary environment. The professional communities represented by the abovementioned roleplayers have different – and very often conflicting – approaches to the way in which they conduct research and produce new knowledge. They are from different *worlds*. For example, any clinical healthcare researcher should be able to conduct a Cochrane systematic literature review. Researchers from other domains also base their research on a rigorous investigation of existing theories and knowledge, even though they may not have heard about Cochrane before. The mindset with which a systematic review has to be executed fits the bottom-up development approach De Bruin *et al.* (2005). The top-down approach followed in this study, is aligned with a systems engineering mindset.

Few persons would undergo medical treatment if it was not confirmed to be effective and safe by means of a randomized, controlled trial. These trials are extremely costly and time-consuming. It is moreover unethical to conduct any research involving humans and animals if any adverse outcome whatsoever is suspected. Engineers and technologists, on the other hand, can usually afford to learn from experiments with adverse outcomes. In fact, these adverse outcomes are often a deliberate part of the design of the experiments. Furthermore, enterprise engineers and health economists are restricted by the timelines of their experiments, since it usually takes a few years before the effect of an enterprise model can be measured.

The TMSMM is designed to be accessible and useful to researchers and practitioners from any discipline or profession concerned with telemedicine. A number of research outputs were produced during the course of this study. These outputs were reviewed by and presented to different audiences from different research domains.

10.3.2 The world of everyday life

The theoretical framework of the TMSMM was used as basis for the development of a maturity assessment tool, which although used for the purposes of this study, can also be used for future assessments. This tool, for assessing telemedicine services, can also be effective in providing guidelines based on this assessment.

It was shown, furthermore, that the design of the TMSMM allows for results from a cohort of individual service descriptions and assessments to be aggregated along all dimensions towards an output that is suitable for interpretation by external stakeholders, researchers, service providers and strategic-level decision makers. In particular a cohort case study provided insights into selected teleradiology services in South Africa.

10.4 Future Research

Where do we want to do? What are the next steps to take?

The following topics should receive priority in future research based on the TMSMM developed in this study:

10.4.1 Longitudinal studies

The scope of this study includes the development, verification and internal validation of a telemedicine maturity model. However, the standard timeframe of a doctoral study does not allow for a completely comprehensive examination into the development, verification, internal validation and external validation of enterprize models, such as maturity models.

The opportunity exists for future work where an "as-is" maturity assessment of a telemedicine service may be used as point of departure. The purpose of such a study would then be to follow the maturation path of such (a) telemedicine service(s) and in doing so contribute (or not) to the external validity of the TMSMM.

10.4.2 Assessment from viewpoint of stakeholder

Khoja *et al.* (2013*a*) present different questionnaires to different stakeholders (for example, clients and service providers). Ideally, the assessment should be done by groups of stakeholders who can collectively contribute to the assessment of all microlevel, mesolevel and macrolevel process areas. However, it is not always possible to get all such roleplayers together at any one time, so future researchers should perhaps consider which roleplayer(s) should be involved in the assessment of which capability area, so that only the appropriate capability statements can be presented to them.

10.4.3 Further iterations of the TMSMM

An iterative design approach was followed in the development of the TMSMM. Future research would therefore need to include further iterations in the development of the TMSMM. Specific focus areas are outlined below:

10.4.3.1 Standardized descriptions

For purposes of this study the facilitator formulated the descriptions for each capability areas. The data warehouse was filled with descriptions for 28 services, and it was therefore possible to identify recuring descriptions. The data integrity and the usability of the assessment methodology could be enhanced if the facilitator was able to select from a list (e.g. in the form of drop-down boxes) of typical descriptions for that particular capability area.

10.4.3.2 Descriptive, prescriptive and comparative maturity model

De Bruin *et al.* (2005) explain that a deeper understanding of the "as-is" domain situation is firstly achieved by means of the descriptive maturity model which was accomplished in this study. According to De Bruin *et al.* (2005), after the maturity model has been applied a sufficient number of times, it can be developed into a prescriptive model. Upon completion of an assessment, using the TMSMM, the analyst can derive suggested actions to enhance maturity. A topic for future research is to further develop the TMSMM into a prescriptive model. Finally, once the TMSMM has been applied to a wide range of organizations and sufficient data were obtained to enable valid comparisons, the TMSMM can evolve into a comparative maturity model.

10.4.3.3 The role of the facilitator

Future work on the development of the TMSMM should also focus on the role of the assessment facilitator. It is common practice with respect to many other maturity models that the assessment is facilitated by a person who is specifically trained for this purpose. A detailed procedure for the training of TMSMM facilitators should be part of the assessment methodology, especially when the model is developed from a descriptive to a prescriptive to a comparative model.methodology, particularly as the model is developed in stages from a descriptive, to a prescriptive and then finally into a comparative model.

10.4.3.4 Meso- and macrolevel capability areas

The TMSMM allows for an unrestricted number of microlevel processes. For example, if a telemedicine service involves seven microlevel capturing processes, each of these processes is simply defined and assessed one by one. Currently, only one mesolevel and one macrolevel can be accommodated.

In the execution of some case studies more than one mesolevel had to be created. For example, in the case of a service between a primary care clinic and a secondary hospital, two physical infrastructures (mesolevel *Man* domain) are involved. This is in line with an observation by Hicks *et al.* (2004) that the *community* can be further subdivided into at least two elements. As an example, they mention the service delivery (hub) community and the recipient (remote) community. Future versions of the TMSMM should allow assessment of all these mesolevel environments.

10.4.4 Refining capability statements

In this study the number of capability statements per capability area was deliberately limited to two statements per maturity level. Future iterations of the TMSMM could benefit from increasingly detailed capability statements. As part of the expert interview process, two experts highlighted two issues that were not explicitly addressed by any of the capability statements. It is possible. It is possible that more such issues will surface as the TMSMM is applied to more services. By allowing more capability statements per capability area, the comprehensiveness of the TMSMM could be enhanced.

10.4.5 Cohort studies

Chapter 9 confirmed that the TMSMM can be generalized. Two cohort studies demonstrated the potential of the TMSMM to be used as a research tool to determine the maturity status of a certain cohort of telemedicine services. However, Hartmann and Van Dyk (2013) are currently using the TMSMM as part of an MEng (Management) research study to assess telemedicine services in the public health sector of the Western Cape. Future work could include other cohort studies, for example focusing on certain telemedicine specializations or comparing the telemedicine services of different healthcare systems.

10.4.6 Development of specific assessment tools

Viljoen (In process) is currently conducting an MEng (Management) study in collaboration with the *Groupe Speciale Mobile Association* (GSMA). The purpose of that study is to develop a tool to describe and assess mhealth services in low- to middle-income countries. This tool, although based on the TMSMM, is not a reference model, since it refers to specific technology and standards. Futhermore, whereas the maturity assessment methodology of the TMSMM is described in generic terms, Viljoen (2013) is developing a specific tool to assist in the description and assessment of these mhealth services. This paves the way for further studies to be pursued wherein assessment tools specific to certain telemedicine applications, could be developed.

10.5 Conclusion

A multidisciplinary effort is needed to launch and sustain the potential contribution that telemedicine could offer to the quality and accessibility of healthcare services. The TMSMM serves as a frame of reference for the assessment and optimization of telemedicine services in a consistent, systematic and systemic way, that spans several academic and professional domains and thereby contributing to both the scientific and practical worlds of telemedicine.

Appendices

Appendix A

Peer Reviewed Research Outputs

A.1 The International Conference on eHealth, Telemedicine, and Social Medicine

A.1.1 2010: Towards a regional innovation system for telemedicine in South Africa

Van Dyk, L., Groenewald, M. and Abrahams, J.F. (2010). Towards a Regional Innovation System for Telemedicine in South Africa. *In: Second International Conference on eHealth, Telemedicine, and Social Medicine, 2010. ETELEMED'10.*, pp. 1-4. IEEE.

A.1.2 2012: A maturity model for telemedicine implementation

Van Dyk, L., Schutte, C.S. and Fortuin, J.B. (2012b). A maturity model for telemedicine implementation. *In: The Fourth International Conference on eHealth, Telemedicine and Social Medicine.* Valencia, Spain.

A.2 The Conference of the Southern African Institute for Industrial Engineering

A.2.1 2010: Telemedicine - Leverage competitive advantage through the use if ICT investment

Van Dyk, L. (2010). Telemedicine - Leverage Competitive Advantage through the use if ICT Investment. *In: Proceedings of the 24th Conference of the Southern African Institute for Industrial Engineering.* Krugersdorp, South Africa.

A.2.2 2011: A systems engineering approach to telemedicine system implementation

Van Dyk, L., Fortuin, J. and Schutte, C. (2011). A systems engineering approach to telemedicine system implementation. *In: International Conference on Industrial Engineering, Systems Engineering and Engineering Management for Sustainable Global Development.* Spier.

A.2.3 2012: Business models for sustained ehealth implementation: lessons from two continents

In 2012 the 42th International Conference for Computers and Industrial Engineering co-incided with the annual conference of the Southern African Institute for Industrial Engineering.

Van Dyk, L., Wentzel, J., Van Gemert-Pijnen, L., Van Limburg, M. and Schutte, C.S. (2012a). Business models for sustained ehealth implementation: Lessons from two continents. *In:Proceedings of the 42th International Conference for Computers and Industrial Engineering* Cape Town, South Africa.

A.2.4 2013: An assessment of the maturity of teleradiology services within the South African public healthcare system

Hartmann, A.H. and Van Dyk, L. (2013). An Assessment of the Maturity of Teleradiology Services within the South African Public Healthcare System. *In: Proceedings of the 25th Conference of the South African Institute for Industrial Engineering.* SAIIE, Stellenbosch.

A.2.5 2013: Assessing the technology acceptance of cell phones within the context of the primary health care system of South Africa

Snyders, F. and Van Dyk, L. (2013). Assessing the Technology Acceptance of Cell Phones within the Context of the Primary Health Care System of South Africa. *In: Proceedings of the 25th Conference of the South African Institute for Industrial Engineering*. SAIIE, Stellenbosch.

A.3 The International eHealth Telemedicine and Health ICT Forum

A.3.1 2011: A framework for the assessment of teleradiology in South Africa: An Eastern Cape Case Study

Haumann, C., Van Dyk, L. and Fortuin-Abrahams, J. (2011). A framework for the assessment of teleradiology in South Africa: An Eastern Cape Case Study. *In: Proceedings of The International eHealth Telemedicine and Health ICT Forum*, pp. 144-148. Luxembourgh.

A.3.2 2011: A telemedicine system to increase patient's access to specialised cardiac care for assisting remote diagnosis.

Triegaardt, M., Doubell, A. and Van Dyk, L. (2011). A telemedicine system to increase patient's access to specialised cardiac care for assisting remote diagnosis. *In: Proceedings of The International eHealth Telemedicine and Health ICT Forum*, pp. 226-229. Luxembourgh.

A.3.3 2011: Meeting the demand for skilled foetal ultrasound services in the Boland/Overberg public health district

Uys, N. and Van Dyk, L. (2011). A health systems engineering approach to meet the demand for skilled Foetal Ultrasound Services in the Western Cape. *In: Proceedings of The International eHealth Telemedicine and Health ICT Forum.*, pp. 480-483. Luxembourgh.

A.3.4 2011: A South African national telemedicine survey

Fortuin, J.B. and Van Dyk, L. (2011). A South African National Telemedicine Survey. *In: Proceedings of The International eHealth Telemedicine and Health ICT Forum*. pp. 783-786. Luxembourgh.

A.3.5 2012: Yardsticks for telemedicine maturity: A teleradiology case study

Triegaardt, M. and Van Dyk, L. (2012). Yardsticks for telemedicine maturity: A teleradiology case study. *In: Proceedings of The International eHealth Telemedicine and Health ICT Forum.*, pp. 312-316. Luxembourgh.

A.3.6 2013: A staged telemedicine reference tool for optimization of telemedicine services

Van Dyk, L. (2013). A staged telemedicine reference tool for optimization of telemedicine services. *In: Proceedings of The International eHealth Telemedicine and Health ICT Forum.* Luxembourgh.

A.4 Book Chapters

These chapters are subjected to copyright. Hence, only the front page of each chapter is included.

A.4.1 2012: Clinical-pull approach to telemedicine implementation policies using health informatics in the developing world

Treurnicht, M.J. and Van Dyk, L. (2012). Clinical-pull approach to telemedicine implementation policies using health informatics in the developing world. *In: Telemedicine and E-Health Services, Policies, and Applications: Advancements and Developments*. IGI Global.

A.4.2 2013: The telemedicine service maturity model: A Framework for the measurement and improvement of telemedicine services

Van Dyk, L. and Schutte, C.S. (2013). The Telemedicine Maturity Model: A generic for the measurement and improvement of telemedicine services. *Provisional Chapter in:Telemedicine*, Intech Open Science. ISBN 980-953-307-714-2.

A.5 The Southern African Journal for Industrial Engineering

Van Dyk, L. and Schutte, C.S. (2012). Developing a telemedicine maturity model. *Southern African Journal for Industrial Engineering*, vol. 23, no. 2, pp. 61-72.

A.6 Miscellaneous

A.6.1 2011:eHealth assessment survey amongst members of the South African Department of Health (DoH)

Van Dyk, L. and Fortuin, J. (2011). eHealth assessment survey amongst members of the South African Department of Health (DoH). *In: Proceedings of the 2nd South African Telemedicine and eHealth Conference and 16th ISfTeH International Conference,* Medical Research Council. Cape Town.

A.6.2 2012: Meta-study of telemedicine services

Chapter from MEng thesis completed under supervision of Van Dyk:

Van Zyl, A.J. (2012). Chapter 4: A Meta-Study of Telemedicine Services. *In:An Information System to Support Telemedicine Projects in South Africa.* MScEng, Stellenbosch University.

Appendix B

Ethical Approval

Investigator Responsibilities

Protection of Human Research Participants

Some of the responsibilities investigators have when conducting research involving human participants are listed below:

1. Conducting the Research. You are responsible for making sure that the research is conducted according to the HREC approved research protocol. You are also responsible for the actions of all your co-investigators and research staff involved with this research.

2. Participant Enrolment. You may not recruit or enrol participants prior to the HREC approval date or after the expiration date of HREC approval. All recruitment materials for any form of media must be approved by the HREC prior to their use. If you need to recruit more participants than was noted in your HREC approval letter, you must submit an amendment requesting an increase in the number of participants.

3. Informed Consent. You are responsible for obtaining and documenting effective informed consent using **only** the HREC-approved consent documents, and for ensuring that no human participants are involved in research prior to obtaining their informed consent. Please give all participants copies of the signed informed consent documents. Keep the originals in your secured research files for at least fifteen (15) years.

4. Continuing Review. The HREC must review and approve all HREC-approved research protocols at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the HREC approval of the research expires, **it is your responsibility to submit the continuing review report in a timely fashion to ensure a lapse in HREC approval does not occur.** If HREC approval of your research lapses, you must stop new participant enrolment, and contact the HREC office immediately.

5. Amendments and Changes. If you wish to amend or change any aspect of your research (such as research design, interventions or procedures, number of participants, participant population, informed consent document, instruments, surveys or recruiting material), you must submit the amendment to the HREC for review using the current Amendment Form. You **may not initiate** any amendments or changes to your research without first obtaining written HREC review and approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the HREC should be immediately informed of this necessity.

6. Adverse or Unanticipated Events. Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research related injuries, occurring at this institution or at other performance sites must be reported to the HREC within **five (5) days** of discovery of the incident. You must also report any instances of serious or continuing problems, or non-compliance with the HRECs requirements for protecting human research participants. The only exception to this policy is that the death of a research participant must be reported in accordance with the Stellenbosch Universtiy Health Research Ethics Committee Standard Operating Procedures www.sun025.sun.ac.za/portal/page/portal/Health_Sciences/English/Centres%20and%20Institutions/Research_Development_Support/Ethics/Application_package All reportable events should be submitted to the HREC using the Serious Adverse Event Report Form.

7. Research Record Keeping. You must keep the following research related records, at a minimum, in a secure location for a minimum of fifteen years: the HREC approved research protocol and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence from the HREC

8. Reports to the MCC and Sponsor. When you submit the required annual report to the MCC or you submit required reports to your sponsor, you must provide a copy of that report to the HREC. You may submit the report at the time of continuing HREC review.

9. Provision of Emergency Medical Care. When a physician provides emergency medical care to a participant without prior HREC review and approval, to the extent permitted by law, such activities will not be recognised as research nor will the data obtained by any such activities should it be used in support of research.

10. Final reports. When you have completed (no further participant enrolment, interactions, interventions or data analysis) or stopped work on your research, you must submit a Final Report to the HREC.

11. On-Site Evaluations, MCC Inspections, or Audits. If you are notified that your research will be reviewed or audited by the MCC, the sponsor, any other external agency or any internal group, you must inform the HREC immediately of the impending audit/evaluation.

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Approval Notice
New Application

23-Nov-2012
Van Dyk, Liezl L

Ethics Refernce #: S12/11/277

Title: **An investigation on the factors that influence the success rate of telemedicine services in the public health sector of South Africa.**

Dear Mrs. Liezl Van Dyk,

The **New Application** received on **05-Nov-2012**, was reviewed by members of **Health Research Ethics Committee 1** via Expedited review procedures on **23-Nov-2012** and was approved.
Please note the following information about your approved research protocol:

Protocol Approval Period: **23-Nov-2012 -23-Nov-2013**

Please remember to use your **protocol number** (**S12/11/277**) on any documents or correspondence with the HREC concerning your research protocol.

Please note that the HREC 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.

After Ethical Review:
Please note a template of the progress report is obtainable on www.sun.ac.za/rds and should be submitted to the Committee before the year has expired.
The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.
Translation of the consent document to the language applicable to the study participants should be submitted.

Federal Wide Assurance Number: 00001372
Institutional Review Board (IRB) Number: IRB0005239

The Health Research Ethics Committee complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel: +27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.
For standard HREC forms and documents please visit: www.sun.ac.za/rds

If you have any questions or need further assistance, please contact the HREC office at 0219389657.

Included Documents:
Consent Form
Synopsis
Application Form
Checklist
Investigators declaration
Protocol

Sincerely,

Franklin Weber

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

TITLE OF THE RESEARCH PROJECT:

An investigation on the factors that influence the success rate of telemedicine services in the public health sector of South Africa

REFERENCE NUMBER:

PRINCIPAL INVESTIGATOR: Liezl van Dyk CONTACT NUMBER: 021 808 3733

ADDRESS:
Health Systems Engineering Research Group
Industrial Engineering Department
Stellenbosch University

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff or doctor any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, 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.

This study has been approved by the **Health Research Ethics Committee at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is Telemedicine?

If the word *telemedicine* is considered semantically, telemedicine can by defined as the delivery of healthcare services (*medicine)* where distance is an issue (*tele*). The ability to deliver telemedicine services is mainly accredited to the advances and use of information and communication technology (ICT).

Most of the time telemedicine services are being applied without the service being specifically mentioned. Take for example (1) the picture archiving and communication system (PACS) used by radiographers. PACS is used to store X-Ray images on a central server accessible from different sites (hospital, clinic, general practitioner) and the different role players involved in the process. Nowadays prescriptions are sent via e-mail to the patient in need.

In 1998, the South African National Department of Health (DoH) published a telemedicine strategy in which they recognised the potential of telemedicine, to give previously isolated communities access to healthcare. Since then, many telemedicine services have been deployed in the public health sector of South Africa. Although it is not clear if these services are really working as intended and which factors influence the success of such services.

What is this research study all about?

The purpose of this study is to determine the factors that influence the success of telemedicine service (although they might not be known as such) deployment in the public health sector of South Africa.

Why have you been invited to participate?

The hospital or clinic at which you are currently working was considered for this study due to the fact that this institution is part of a telemedicine services pilot study. Specifically the MRC-MTN telemedicine workstation. This study is not limited to the MRC-MTN workstation, the idea is to focus on any telemedicine services which can be identified.
You were identified as someone who is in one way or another influenced by or participating in a telemedicine service.

What procedure will be conducted in this research?

Two researchers from the University Stellenbosch will conduct a site visit at your hospital/clinic. It would be highly appreciated if you could spare 2½ hours of your time to take part in this structured workshop together with 2,3 or 4 of your collegues. At this workshop the researchers will facilitate a session during which a number of telemedicine services will be identified, described and evaluated.

Explain any procedures e.g. Volume of blood samples etc. Saliva samples etc.

Are there any risks involved in genetic research?

All potential risks, depending on the specific research protocol, should be discussed transparently. These risks could include detection of unsuspected medical conditions, anxiety, group or individual stigmatisation, employment discrimination, adoption of exclusionary policies, including discriminatory insurance policies, , potential implications of the possible outcomes of the research on other family members even discovery of mis-attributed paternity
The possible need for genetic counselling should also be discussed, if relevant, including who will cover the costs of this service.
Please include any/all of these risks if they may be relevant to your particular research study.

Are there any benefits to your taking part in this study and will you get told your results?

Please explain here whether or not any results will be made known to the participants. If not explain why not e.g. that blood will be stored and only tested at a later date, or that the techniques to be used are experimental and thus possibly unreliable etc. Also indicate that the research may benefit people with a similar condition in the future.
Optional wording:
Your personal results will be made known to you ***only if they indicate*** *that you may:*

- *Have a definite risk for developing a particular disorder.*
- *Have a condition or predisposition to developing a condition that is treatable or avoidable e.g. by a lifestyle modification.*
- *Need genetic counselling.*

How long will your blood be stored and where will it be stored?

Answer this question according to the specifics of your research study. Be transparent and include sufficient detail. If you are likely to ship stored specimens to another country either now or at a later date, this needs to be clarified up front.

If your blood is to be stored is there a chance that it will be used for other research?

Your blood will only be used for genetic research that is directly related to

………………………………………..…………… (*the disease or condition or reason for your original research)*.
Also if the researchers wish to use your stored blood for **additional research in this field** they will be required to apply for permission to do so from the Health Research Ethics Committee at Stellenbosch University.

If you do not wish your blood specimen to be stored after this research study is completed you will have an opportunity to request that it be discarded when you sign the consent form.

How will your confidentiality be protected?

Please explain this in detail. This is particularly important with collaborative research when the specimens will be shipped to a laboratory abroad. Will the specimens be anonymised, or linked only to demographic/clinical information or will it remain possible to link the specimens to identifying information. Is there a remote possibility that information that comes to light in the future may be beneficial to the participant or possibly have unpleasant implications? If so will an attempt be made to contact participants?

Will you or the researchers benefit financially from this research?

Western Cape Government
Health

STRATEGY & HEALTH SUPPORT
healthres@pgwc.gov.za
tel: +27 21 483 9907: fax: +27 21 483 9895
5th Floor, Norton Rose House,, 8 Riebeek Street, Cape Town, 8001
www.capegateway.gov.za)

REFERENCE: RP 165/2012
ENQUIRIES: Ms Charlene Roderick

Department of Industrial Engineering
Stellenbosch University
Private bag X1
Matieland, 7600

For attention: **Liezl van Dyk and André Hartmann**

Re An investigation on the factors that influence the success rate of telemedicine services in the public health sector of South African

Thank you for submitting your proposal to undertake the above-mentioned study. We are pleased to inform you that the department has granted you approval for your research.

Please contact the following people to assist you with any further enquiries.

Ceres Hospital	**Mrs EM Prins**	**Contact No. 023 316 9626**

Kindly ensure that the following are adhered to:

1. Arrangements can be made with managers, providing that normal activities at requested facilities are not interrupted.
2. Researchers, in accessing provincial health facilities, are expressing consent to provide the department with an electronic copy of the final report within six months of completion of research. This can be submitted to the provincial Research Co-ordinator (healthres@pgwc.gov.za).
3. The reference number above should be quoted in all future correspondence.

Yours sincerely

DR NT Naledi
DIRECTOR: HEALTH IMPACT ASSESSMENT
DATE: 4/4/2013
CC **DR L PHILLIPS** **DIRECTOR: CAPE WINELANDS**

Page 1of 1

Appendix C

Summary of Answers to Interview Questions

The purpose of these interviews is to determine whether or not the TMSMM satisfy all of the design requirements. The interview questions are aligned with the design requirements. The answers to these questions are summarized in this appendix. A requirement for ethical clearance was that responses are presented in such a way that it cannot be linked a specific expert.

List of Questions

Question C.1: Which telemedicine services are you involved with either as participant or as developer?

The MRC-workstation was installed at our facilities before I got involved here. So, the workstation is standing here, but I do not really know how to use it. We have our own telemedicine services in that we use our own cellphones to communicate with each other either through telephone calls or text or the sending of images.
At the moment we are driving the implementation of telemedicine services for the National Department of Health in one of the provinces with one tertiary hospital as hub. We are also currently in the planning phases of a so-called virtual hospital.
We rolled out more that 60 telemedicine workstations throughout the country (public health sector). But we also co-ordinate quite a number of projects, involving NGOs and research institutions as well. I also facilitated the drafting of the 2012 national eHealth Strategy.
I have been involved in the telemedicine workstation and a few other telemedicine devices, such a a mobile teleophthalmoscope.

Question C.2: Do/did you use any standard framework or guideline to help with the implementation, operationalizing and optimization of telemedicine services?

When we started with the I search a lot, read a lot and talked to a lot of persons to find guidelines for the implementation of telemedicine, but we did not find anything suitable. So, we developed our own policy, which is very specifically applicable to our situtation.
The telemedicine services which is currently operational developed spontaneously (bottom-up), not according to a specific guideline.
We do have a protocol according to which the telemedicine workstation is deployed.
We did try that eReadiness Questionnaires [(Khoja *et al.*, 2007)] but found that it did not help much on operational level. I therefore compiled my one evaluation survey (of which some issues are roughly based on this other questionnaire, which I will make available to you.) [This survey include the following categories: community involvement; patient demographics, capacity and referral patterns; staff readiness and human resource assessment; general ICT skills; infrastructure and technical readiness; patient consent procedure; connectivity; equipment inventory. The survey also include a significant amount of technical and context specific detail.]"
No

Question C.3: Can you think of any telemedicine service that cannot be described and assessed with the TMSMM?

No, even complex services has the basic components that we used now, e.g. capture, diagnose, transmit. The react component is normally done in the traditional way [not telemedicine], but it is OK that it is part of the model.
From my point of view all telemedicine services can be described by this framework.
I can not imagine a telemedicine service that can not be described by this framework.
Initially I was not sure whether we could use it for the virtual hospital, but when we tried it work. It worked well for the DoH example. As far a my experience with telemedicine is concerned, I can imagine that it can be applied to any telemedicine service.
No, if we had more time, I am certain that we could have described all our services with this framework.
I think if will be tricky to use this framework and tool if you are describing real-time telemedicine. You will need to think very carefully on how the services are broken down into process. It will take some careful consideration, but actually the basic processes of TMSMM is the same as for real-time. As soon as the process breakdown is done, the description and assessment is the same as for store-and-forward. The capability statements may be used differently, for example the user maybe available, but if both users are not available at the same time, you must mark them as sometimes available.

Question C.4: Based on the description and assessment, guidelines are provided concerning further actions to be taken. Would this advice influence your future decisions?

Yes, and there is a great need for something like that.
I think that all of the things that came out of this report are things that we would have thought of in any way. However, the way in which it is presented helps a great deal to organize and prioritise next actions. So, these guidelines will definitely influence the planning process.
Personally, I think I will mostly rely on my experience. I do agree with the significance of the advice. I and think it will be particularly useful for persons with less experience. Not the report - as such - but the actual use of the tool, made be realize of issues we still need to consider when implementing the virtual hospital.
In our [clinical] context people are conditioned to think in terms of protocols. They do not think in systems. This framework will definitely help us in this context to think in systems and consider all aspects related to the service. Maybe the value of this is not so much that it provide advice, but that it makes people think about what to do next.
It does not provide exact instructions on what to do next. It is not very specific. Whoever decide on further actions will have to base that on other information, knowledge and experience. However, dashboard and report will definitely guide further decision making.
It surely will. Just by doing this assessment, my future decisions can be influenced.

Question C.5: Do you think the TMSMM can be used to educate other role players and explain standards about telemedicine

Definitely. We are increasingly realizing the importance of telemedicine training, not only for purposes of skills development, but also for awareness and marketing. This can be a very useful tool for that purpose.
Definitely.
I agree. What makes is particulary useful is that you can use an example with which everyone is familiar. For example, it you use the example of today, together with this framework, it will definitely help to get everyone on the same page.
I believe education and awareness is one of the most important success factors for telemedicine. The technicians do not always understand the needs of the healthcare workers and the other way around. Also, the non-technical (administrative) support personnel needs to understand and be understood. If all role can sit together and use this tool to describe a telemedicine service, it will definitely help them to understand everything that impacts on telemedicine and to help understand each others roles.
It will help different role players concerning the same system to appreciate the whole process. Often the persons at the one end of the process does not how things are working at the other end. It will help to explain and communicated standard ways of doing.
I am not really involved in the education of users, so I cannot really say "yes" or "no".

Question C.6: Will you be able to use the TMSMM on your own?

I do not completely agree. It is easy to understand, but I do not think that I would have been able to use the tool if you did not show me how.
Now that you gone through it with me, yes, but I would not have been able to use it on my own. For example, I was confused by all of these Ms (man, machine ... especially with material), but after you explained it to me, it made sense.
I consider myself a systems thinker. So, I can really relate the TMSMM. It will help the non-system-thinkers, but I am not sure if they will be able to use the tool on their own.
... [Some hesitation] ... no ... I think I will be able to use it on my own, but it is easier to sit with somebody.
I will need some training and practice, but eventually I will be able. The interface is quite user friendly.
The framework makes sense. The detail takes some time to digest.

Question C.7: Which persons/entities should be involved to the definition and assessment of a telemedicine service?

The TMSMM can be used by medical officers and specialist, but also my non-medical staff. It will actually be good if people from both sides are involved.
Medical officers, specialists, administrators, radiographers ...all of them ... It is important to involve a much as possible people.
Like now, it was possible for me to do this on my own, because I am co-ordinating the telemedicine services, but there were issues (for example the internet-issues) on which I was not certain. So, we actually needed someone from IT. In other cases one might need the input of representatives from the facilities.
Even the health care workers from the primary care clinics up to the specialist will be able to contribute to this.
I think you will have different persons contributing to different parts. The nurses and patients know the lower [micro] level processes better, but may possible not be able to comment on the higher level [macro and meso level] processes. Or, on the other hand, district managers may not know about the detail [micro-level] process, but they will be able to tell you about the policies and other higher level issues.
I think any user can contribute, not only the healthcare workers, but also the developers and technicians. You need some inside knowledge to participate here.

Question C.8: Telemedicine services are defined and assessed according to a uniform framework to allow the analysis of a cohort of studies. Who would be interested in this, if any?

I will definitely be interested. And then of course, others in a similar position than I. It will help me alot to know about self-initiated telemedicine services in my district and also what makes telemedicine services in my district successful. I
It is difficult to say. If I can see such a summary which I can relate to, it will be easier to know who will be interested. But I can really see that the fact that all services are mapped with the same framework, can help to compare services and to get a bigger picture.
I know that at a moment a number of people are working on policies with respect to the implementation of telemedicine services. The contribution of role players start here with us on sub-district level and then all inputs are integrated and escalated to national level. The framework measures outcomes consistently according to an uniform scale. It has the potential to provide the evidence needed to support policy-making decisions.
When I started as telemedicine co-ordinater 7 years ago, I had to learn everything from scratch. I had to read a lot and consult with a lot of people. It would have been very nice for me, if I could have had an overview like this back then. I think telemedicine is still very new. There are many people who can learn from reports like these.
Policy makers as well as business consultants and ministries of health. It can also be very useful to research the different level of maturity between the private health sector and the public health sector, especially with the NHI on its way.
I truly hope that government and other decision makers have a look at this. They do not really have an idea of what is going on. They need this type of information.

Question C.9: Does the TMSMM indicate anything about specific standards, specific technologies, concrete implementation detail?

No. This is interesting, because my own evaluation survey include a lot of technical detail, which would not be relevant in other contexts. So, my survey are actually something different.
No
The TMSMM does indicate standards in terms what is typical to each process, but is does not refer to technical standards, such DICOM or HL7. These standards will differ depending on the type of service, e.g. radiology or pathology. So, it is a good thing that the TMSMM is not linked to any technical detail.
No
No, that is one of the reasons why it can be applied to many telemedicine services.
No

Question C.10: Is any of the statements in the TMSMM repeating / contradicting each other?

Not as far as our example is concerned.
I do not think so.
No
Definitely not contradicting. Of course, when assessing the same type of processes the same type of capability statements are repeated. But if the processes are considered one by one, it is not contradicting each other.
Some of the statements are very much the same, but if you look closely you see the slight differences and understand how they follow upon each other.
Nothing that could have picked up.

Question C.11: Does the TMSMM include all issues that impact on the success of telemedicine services?

I think so. You can double-check what is on my own survey with what is in the TMSMM.
Nothing I can think of. Very often people only consider the technology and infrastructure. What is very important about this model is that is considers all other factors. I believe this research is very important.
I believe the most important factor is the human factor. If a someone do not want to use it or is scared of using it , it will not be successful ... but this framework did consider that.
A big thing that is possibly not reflected here, is political will and governance. I know you covered this on macro-level, but it actually impact on micro-level. How is the tenders awarded?
Yes
Yes, as I said about the real-time services, some issues may be viewed and assessed differently, just because it is real-time. For example "The user is available". For real-time both users must be available.

Question C.12: For each aspect that is described, 11 capability statements are provided to help to determine the maturity level of the that aspect. Does each capability statement implicitly include previously listed statements?

Agree.
I think so.
Yes
I immediately grasped that it is designed like that and I experienced it like that. It is quite useful, because instead of having this very long check list, with a few ticks, you actually have a lot of information. I also think it will the summaries, that you referred to in the previous question, easier to digest.
Yes, that is why - at first glance - some statements seem the same.
As far the examples we considered are concerned, yes.

Question C.13: Did you understand what was meant with each capability statement and how it differed from the other statements?

Yes
I said earlier that I would not have known how to use this model, if you did not explain some concepts to me. So, yes, I did understand, but there were some possible ambiguities, which you had to explain.
Yes, I did.
Yes, again it helped with the understanding that the only followed on the other.
Yes, I did.
Yes

Appendix D

Case Studies

Chapter 7 describes a methodology for the assessment of telemedicine services, based on the conceptual TMSMM and capability statements. This methodology comprises of three phases as indicated by Figure D.1. For purposes of this study the first two phases were applied to 28 individual telemedicine services. From these 28 services, two cohort studies were compiled, based on aggregated data from a collection of services.

Case studies as research method is elaborated upon in Section 8.3. This appendix contains some evidence concerning the individual case studies (Section D.1) as well as both of the cohort studies (Sections D.2 and D.3 respectively.)

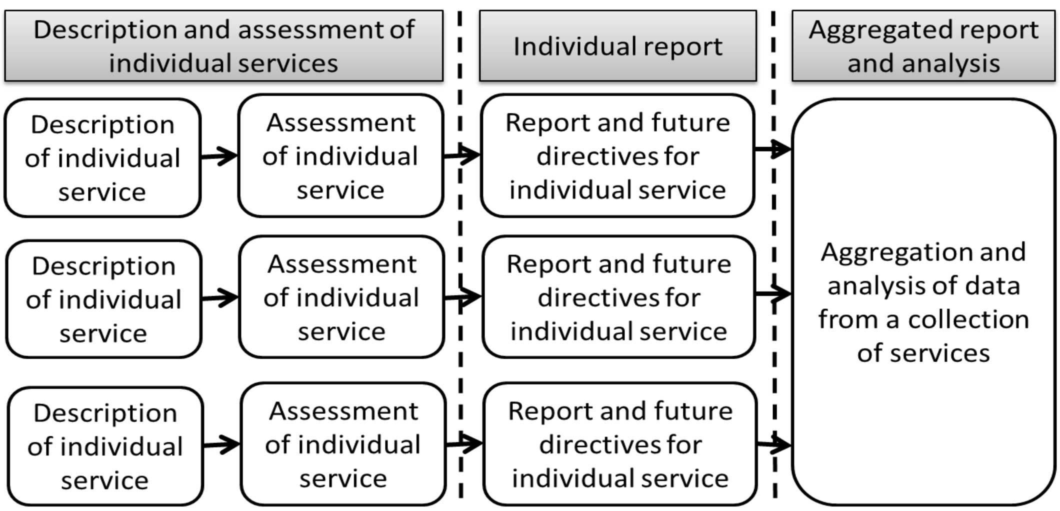


Figure D.1: Phases of the assessment methodology

D.1 Individual Cases

The 28 individual cases are listed in Table D.1 together with the average maturity assessment for each of these domains. The rest of this section is devoted to a detail discussion of two of these services, Sections D.1.2 and D.1.1 respectively.

	Man	Machine	Material	Method	Money
Telecardiology at hospital B	2.3	1.8	1.3	3.2	2.6
Telecardiology at hospital C	3.4	3.4	2.6	2.6	2.9
Telecardiology at hospital D	2.3	2.0	1.5	3.2	2.6
Telecardiology at hospital F	2.3	2.0	1.1	3.2	2.7
Telecardiology at hospital G	2.4	2.4	1.7	3.3	2.7
Telecardiology at hospital I	1.5	2.0	1.4	3.1	2.0
Teleconsultation (pediatrics) at hospital C	3.9	1.9	2.3	2.6	2.8
Teleconsultation (post-operation) at hospital C	3.3	1.9	2.3	2.6	2.6
Teleconsultation at hospital B	2.2	1.8	1.4	3.3	2.4
Teleconsultation at hospital F	1.1	2.3	1.2	3.4	4.0
Teleconsultation at hospital I	1.3	2.9	2.6	2.6	3.2
Teledermatology at hospital B	2.3	2.0	1.3	3.3	2.0
Teledermatology at hospital C	1.9	2.3	2.8	2.9	2.1
Teledermatology at hospital D	1.6	1.9	1.6	2.7	2.6
Teledermatology at hospital F	2.4	2.0	1.8	3.3	2.6
Teledermatology at hospital G	2.3	2.2	1.9	3.2	2.6
Teledermatology at hospital I	1.9	2.2	1.6	3.1	2.2
Tele-education at hospital C	3.8	4.2	2.3	2.9	2.9
Teleopthalmology at hospital C	2.0	1.6	1.3	1.6	1.2
Teleradiology at hospital A	2.8	2.3	2.8	3.1	3.2
Teleradiology at hospital B	2.2	3.1	2.6	3.6	3.1
Teleradiology at hospital C	4.4	3.7	2.7	3.6	3.4
Teleradiology at hospital D	2.3	2.8	2.6	3.3	3.7
Teleradiology at hospital E	4.6	4.7	4.7	4.7	4.7
Teleradiology at hospital F	2.5	2.2	1.8	3.5	3.0
Teleradiology at hospital H	2.8	2.9	2.8	3.0	3.6
Teleradiology at hospital I	1.7	2.2	1.9	3.2	2.2
Teleopthalmology at hospital Ad Hoc	1.0	2.5	2.5	1.9	1.5

Table D.1: All services included in this study

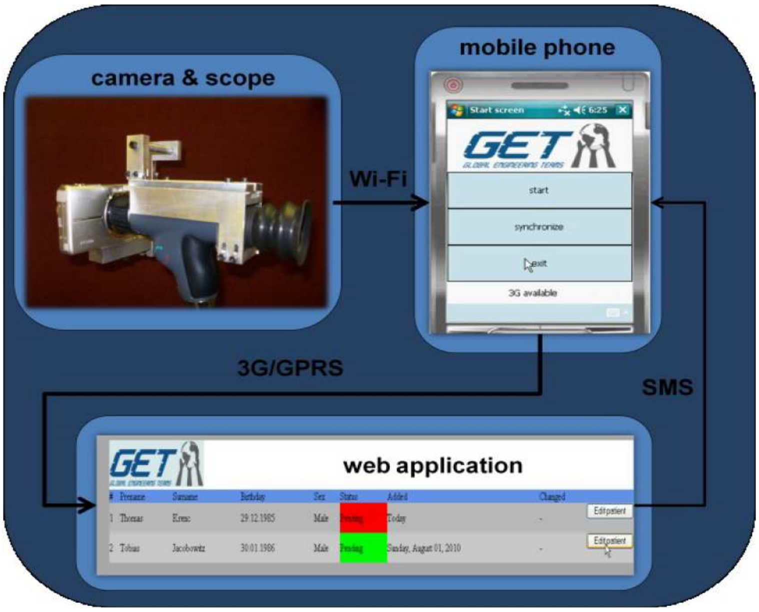


Figure D.2: Ophthalmoscope system (Blanckenberg *et al.*, 2011)

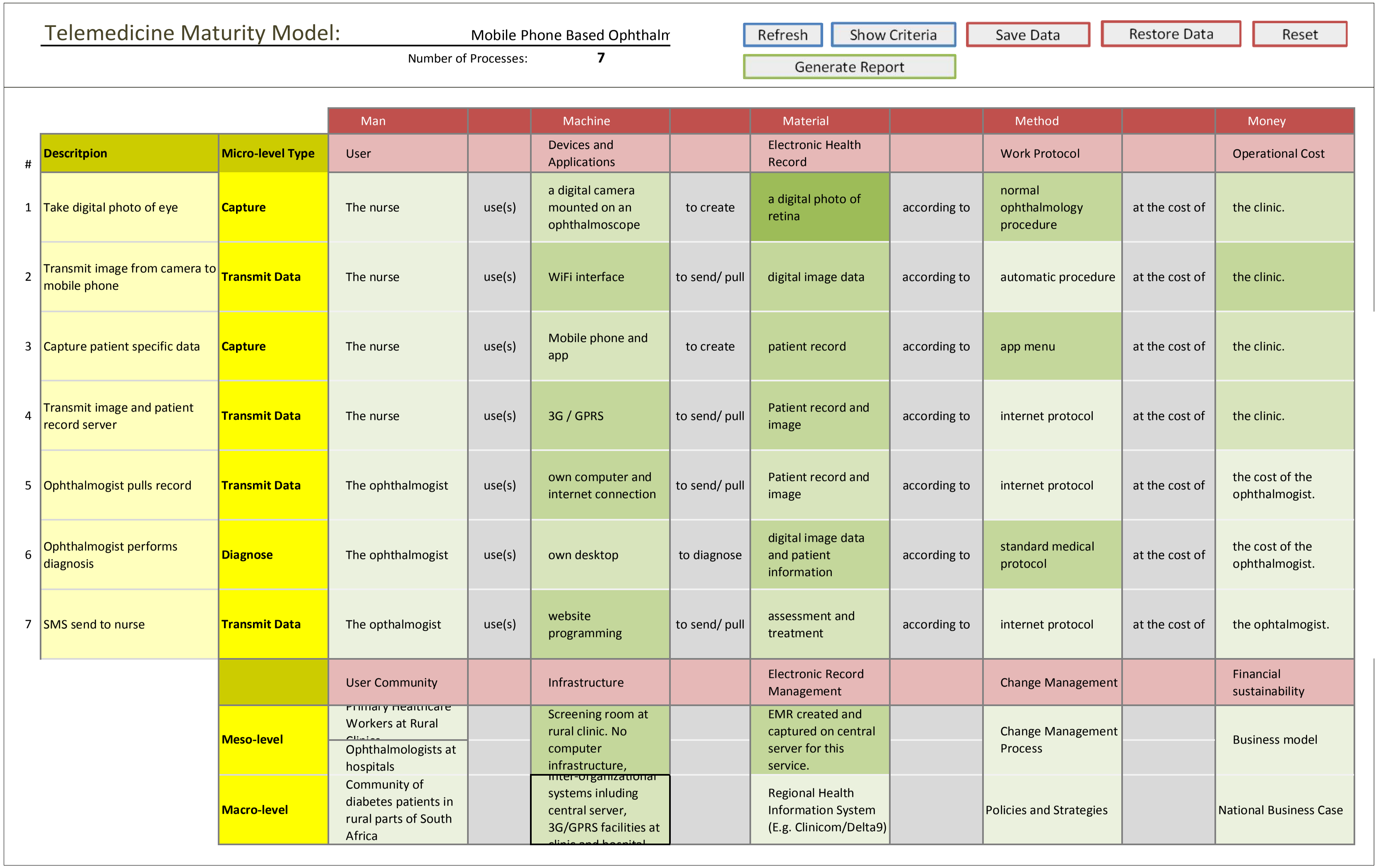
D.1.1 A teleophthalmology service

The description of this service, together with its assessment dashboard is shown in Figure D.3. The report with recommendations is included in Figure D.4 and D.5.

Blanckenberg *et al.* (2011) published a detail description of this service. The primary author of this paper, Dr Mike Blanckenberg, were one of the experts that were consulted in the process of verification and validation. The maturity assessment of this service were executed as part this expert interview. Figure D.3 shows the output of this process.

This service aims to support nurses in rural clinics of South Africa in the screening of diabetes patients for diabetic retinopathy, by means of single field fundus photography. An opthalmoscope system was developed as shown in Figure D.2 (Blanckenberg *et al.*, 2011). A standard Welch Allyn Panoptic ophthalmoscope is mounted to digital camera.

The images captured by the digital camera are sent by wireless connection to a smartphone on which custom software is installed. The image verification algorithm checks the images for blur, color, resolution, outline, border and whether the optical disc is within the image. The nurse decides acccordingly whether the images are acceptable to be uploaded to the web platform. An opthalmologist, who are typically situated at a tertiary hospital then log into the web platform to retrieve the images and submit a diagnosis. The nurse then receives an SMS on the smartphone and can review the recommendation and treatment prescription (Blanckenberg *et al.*, 2011).



#	Descritpion	Micro-level Type	Man		Machine		Material		Method		Money
			User		Devices and Applications		Electronic Health Record		Work Protocol		Operational Cost
1	Take digital photo of eye	Capture	The nurse	use(s)	a digital camera mounted on an ophthalmoscope	to create	a digital photo of retina	according to	normal ophthalmology procedure	at the cost of	the clinic.
2	Transmit image from camera to mobile phone	Transmit Data	The nurse	use(s)	WiFi interface	to send/ pull	digital image data	according to	automatic procedure	at the cost of	the clinic.
3	Capture patient specific data	Capture	The nurse	use(s)	Mobile phone and app	to create	patient record	according to	app menu	at the cost of	the clinic.
4	Transmit image and patient record server	Transmit Data	The nurse	use(s)	3G / GPRS	to send/ pull	Patient record and image	according to	internet protocol	at the cost of	the clinic.
5	Ophthalmogist pulls record	Transmit Data	The ophthalmogist	use(s)	own computer and internet connection	to send/ pull	Patient record and image	according to	internet protocol	at the cost of	the cost of the ophthalmogist.
6	Ophthalmogist performs diagnosis	Diagnose	The ophthalmogist	use(s)	own desktop	to diagnose	digital image data and patient information	according to	standard medical protocol	at the cost of	the cost of the ophthalmogist.
7	SMS send to nurse	Transmit Data	The opthalmogist	use(s)	website programming	to send/ pull	assessment and treatment	according to	internet protocol	at the cost of	the ophtalmogist.
			User Community		Infrastructure		Electronic Record Management		Change Management		Financial sustainability
		Meso-level	Primary Healthcare Workers at Rural Clinics; Ophthalmologists at hospitals		Screening room at rural clinic. No computer infrastructure,		EMR created and captured on central server for this service.		Change Management Process		Business model
		Macro-level	Community of diabetes patients in rural parts of South Africa		Inter-organizational systems inluding central server, 3G/GPRS facilities at clinic and hospital		Regional Health Information System (E.g. Clinicom/Delta9)		Policies and Strategies		National Business Case

Figure D.3: Description and assessment of a teleophthalmology service

Communication between the mobile rural clinics (nurses) and the web platform is established by means of mobile phone networks are used instead of fixed line communication, since the former is more readily available in rural settings. The computational power of a suitable mobile phone, furthermore, eliminates the requirement for a computer in the clinic.

This service is still in pilot phase. The micro-level processes of the machine, method and material domains were assessed as either repeatable (level 2) or defined (level 3), depending on the specific capture/ transmit/ diagnose process under consideration. In this case both users (nurse and ophthalmologist) were only available during controlled experiments and therefore these micro-level processes.

The meso-level, neither the healthcare community nor the larger society is aware of this service (level 0), the meso-level physical infrastructure as well as electronic medical records as defined (level 3). The macro-level inter-organizational infrastructure is managed (level 2). Electronic Health Record systems do exist, but it is not integrated with the telemedicine service (level 1). Neither change management processes nor policies and strategies nor business models exist (level 0).

clearpage

D.1.2 Teleradiology Service of a Private Hospital Group in South Africa

The description of this service, together with its assessment dashboard is shown in Figure D.6. The report with recommendations is included in Figure D.7.

This telemedicine service is entirely digitized. It is a good practice example. All processes for all domains are gauged at a maturity level of either 5a or 5b. The radiology information system (RIS) is integrated with the hospital information system (HIS) as well as an Electronic Health Record (EHR) system. The process start where the EHR is retrieved from the HIS. The referral information already appear on the system.

The radiographer then follow a well defined work procedure to take the radiolograph with equipment that is procured, installed and maintained according to system standards and service levels. This work procedure includes measurable quality controls. The performance of the radiographer is also monitored. The patient (or the medical fund of the patient) is held accountable for each of the capture/ diagnose and transmit processes.

As soon as the radiographer is satified that the radiograph is capture according to an acceptable quality, the image is saved on the server of the EHR system. The radiograph is transmitted from the radiography centre to the server via the

Telemedicine Service Maturity Assessment Report

Opthalmology Research and Development Phase **14 May 2013**

Capture - **Take digital photo of eye**

	Man		Machine		Material		Method		Money
	The nurse	use(s)	a digital camera mounted on an ophthalmoscope	to create	a digital photo of retina	according to	normal ophthalmology procedure	at the cost of	the clinic.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	experiment and pilot	Continue with development to accomplish effectiveness, availability and reliability.	quality standards	Determine appropriate and measurable quality metrics.	effective	Conduct a method study on existing process to develop a standard process.	consitent, but temporary	Secure medium-term development funds.

Transmit - **Transmit image from camera to mobile phone**

	Man		Machine		Material		Method		Money
	The nurse	use(s)	WiFi interface	to send/ pull	digital image data	according to	automatic procedure	at the cost of	the clinic.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	prototype/ pilot	Determine peak bandwidth. Test effectiveness of data transmission under these circumstances.	consistent quality	Define a transmissions protocol.	ad hoc	Indentify available service providers.	consistent, but temporary	Include data transmission funds as standard budget item.

Capture - **Capture patient specific data**

	Man		Machine		Material		Method		Money
	The nurse	use(s)	Mobile phone and app	to create	patient record	according to	app menu	at the cost of	the clinic.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	experiment and pilot	Continue with development to accomplish effectiveness, availability and reliability.	consistent quality	Define quality standards for electronic record.	effective	Conduct a method study on existing process to develop a standard process.	consitent, but temporary	Secure medium-term development funds.

Transmit - **Transmit image and patient record server**

	Man		Machine		Material		Method		Money
	The nurse	use(s)	3G / GPRS	to send/ pull	Patient record and image	according to	internet protocol	at the cost of	the clinic.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	prototype/ pilot	Determine peak bandwidth. Test effectiveness of data transmission under these circumstances.	consistent quality	Define a transmissions protocol.	ad hoc	Indentify available service providers.	consitent, but temporary	Ringfence funds to data transmission.

Transmit - **Ophthalmogist pulls record**

	Man		Machine		Material		Method		Money
	The ophthalmogist	use(s)	own computer and internet connection	to send/ pull	Patient record and image	according to	internet protocol	at the cost of	the cost of the ophthalmogist.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	prototype/ pilot	Determine peak bandwidth. Test effectiveness of data transmission under these circumstances.	uncertain/consistent quality	Define a transmissions protocol.	ad hoc	Indentify available service providers.	R and D / entre-peneur	Ringfence funds to data transmission.

Diagnose - **Ophthalmogist performs diagnosis**

	Man		Machine		Material		Method		Money
	The ophthalmogist	use(s)	own desktop	to diagnose	digital image data and patient information	according to	standard medical protocol	at the cost of	the cost of the ophthalmogist.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	experiment and pilot	Continue with development to accomplish effectiveness, availability and reliability.	consistent quality	Define quality standards for electronic record.	effective	Conduct a method study on existing process to develop a standard process.	R and D / entre-peneur	Secure development funds for next phase.

Figure D.4: Recommendation report for a teleopthalmology service (part 1)

Transmit - **SMS send to nurse**

	Man		Machine		Material		Method		Money
	The opthalmogist	use(s)	website programming	to send/ pull	assessment and treatment	according to	internet protocol	at the cost of	the ophtalmogist.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepreneur	Put measures in place to motivate user to execute this process.	prototype/ pilot	Determine peak bandwidth. Test effectiveness of data transmission under these circumstances.	uncertaing/consitent quality	Define a transmissions protocol.	ad hoc	Indentify available service providers.	R and D / entre-peneur	Ringfence funds to data transmission.

Meso

	Man		Machine		Material		Method		Money
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
0	perceives the service easy to use.	experiment and pilot	is neither appropriate nor available.	0	is kept and stored by user while telemedicine process is in progress.	uncertain/ consistent execution	was not even effective for pilot purposes.	consitent, but temporary	relies on donor funds / seed funds.

Macro

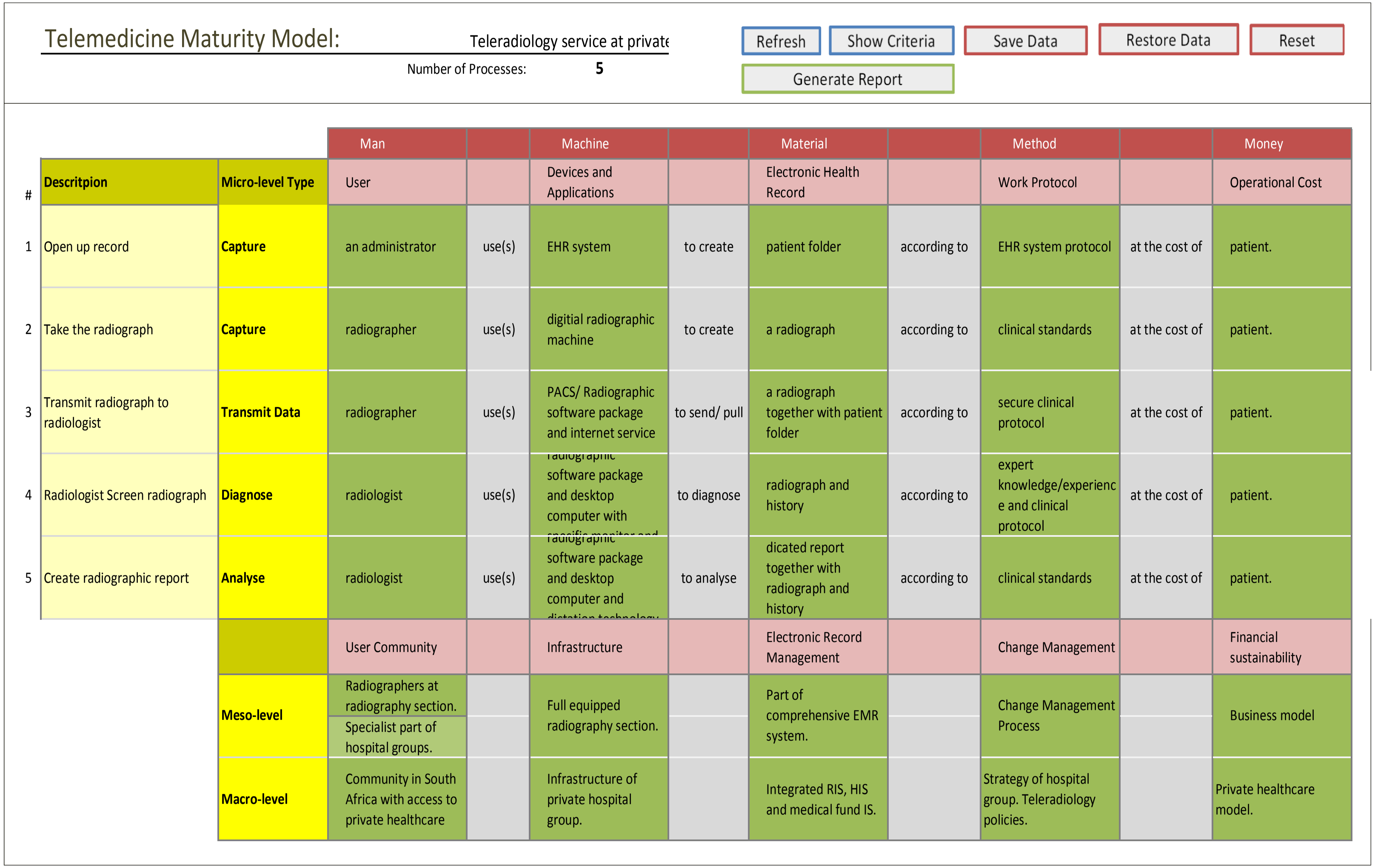
	Man		Machine		Material		Method		Money
	Radiographer	use(s)	CT Scanner	to create	Digital radiographical image	according to	standard protocol	at the cost of	referring hospital.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
entrepeneur	will probably benefit from this service.	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement

Figure D.5: Recommendation report for a teleopthalmology service (part 2)

communications network of the private hospital group. The network is installed and maintained according to specific service levels, which are aligned with the requirements for the teleradiology service.

The radiograph is then pushed to a radiologist within the hospital group, based on the availability and expertise of the radiologist. The radiologist view the radiograph together with the complete EHR, with include the medical history of the patient. The radiologist then dictates his diagnosis and recommendation. His dication is automatically converted into text. After checking the quality of the transcription, the radiologist update the EHR.

The referring doctor are notified once the EHR is updated to include the conclusion and recommendation. All of these processes are clearly defined and monitored.



Telemedicine Maturity Model: Teleradiology service at private

Number of Processes: 5

Refresh | Show Criteria | Save Data | Restore Data | Reset | Generate Report

#	Descritpion	Micro-level Type	Man		Machine		Material		Method		Money
			User		Devices and Applications		Electronic Health Record		Work Protocol		Operational Cost
1	Open up record	**Capture**	an administrator	use(s)	EHR system	to create	patient folder	according to	EHR system protocol	at the cost of	patient.
2	Take the radiograph	**Capture**	radiographer	use(s)	digitial radiographic machine	to create	a radiograph	according to	clinical standards	at the cost of	patient.
3	Transmit radiograph to radiologist	**Transmit Data**	radiographer	use(s)	PACS/ Radiographic software package and internet service	to send/ pull	a radiograph together with patient folder	according to	secure clinical protocol	at the cost of	patient.
4	Radiologist Screen radiograph	**Diagnose**	radiologist	use(s)	radiographic software package and desktop computer with specific monitor and	to diagnose	radiograph and history	according to	expert knowledge/experienc e and clinical protocol	at the cost of	patient.
5	Create radiographic report	**Analyse**	radiologist	use(s)	radiographic software package and desktop computer and dictation technology	to analyse	dicated report together with radiograph and history	according to	clinical standards	at the cost of	patient.
			User Community		Infrastructure		Electronic Record Management		Change Management		Financial sustainability
		Meso-level	Radiographers at radiography section. Specialist part of hospital groups.		Full equipped radiography section.		Part of comprehensive EMR system.		Change Management Process		Business model
		Macro-level	Community in South Africa with access to private healthcare		Infrastructure of private hospital group.		Integrated RIS, HIS and medical fund IS.		Strategy of hospital group. Teleradiology policies.		Private healthcare model.

Figure D.6: Description and assessment of a teleradiology service

Telemedicine Service Maturity Assessment Report

Teleradiology: Private Hospital Group **17 March 2013**

Capture - **Open up record**

	Man		Machine		Material		Method		Money
	an administrator	use(s)	EHR system	to create	patient folder	according to	EHR system protocol	at the cost of	patient.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
standard	Determine appropriate and measurable metrics.	standards and inter-operability	Measure and monitor effectiveness and availability	quality standards	Determine appropriate and measurable quality metrics.	work standards	Identify measurable process inputs and outputs.	consistent and perma-nent	Develop a cost-benefit measure for this telemedicine service.

Capture - **Take the radiograph**

	Man		Machine		Material		Method		Money
	radiographer	use(s)	digitial radiographic machine	to create	a radiograph	according to	clinical standards	at the cost of	patient.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
standard	Determine appropriate and measurable metrics.	standards and inter-operability	Measure and monitor effectiveness and availability	quality standards	Determine appropriate and measurable quality metrics.	work standards	Identify measurable process inputs and outputs.	consistent and perma-nent	Develop a cost-benefit measure for this telemedicine service.

Transmit - **Transmit radiograph to radiologist**

	Man		Machine		Material		Method		Money
	radiographer	use(s)	PACS/ Radiographic software package and internet service	to send/ pull	a radiograph together with patient folder	according to	secure clinical protocol	at the cost of	patient.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
standard	Determine appropriate and measurable metrics.	standards and inter-operability	Define measures for realiability and availability.	quality standards	Put measures in place to track progress of telemedicine service.	work standards	Development measures to monitor adherence to service level agreements.	consistent and perma-nent	Include transmission costs in accounting reports.

Diagnose - **Radiologist Screen radiograph**

	Man		Machine		Material		Method		Money
	radiologist	use(s)	radiographic software package and desktop computer with specific monitor and dictation technology	to diagnose	radiograph and history	according to	expert knowledge/experience and clinical protocol	at the cost of	patient.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
standard	Determine appropriate and measurable metrics.	standards and inter-operability	Measure and monitor effectiveness and availability	quality standards	Determine appropriate and measurable quality metrics.	work standards	Identify measurable process inputs and outputs.	consistent and perma-nent	Develop a cost-benefit measure for this telemedicine service.

Analyse - **Create radiographic report**

	Man		Machine		Material		Method		Money
	radiologist	use(s)	radiographic software package and desktop computer and dictation technology	to analyse	dicated report together with radiograph and history	according to	clinical standards	at the cost of	patient.
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
standard	Determine appropriate and measurable metrics.	standards and inter-operability	Measure and monitor effectiveness and availability	quality standards	Determine appropriate and measurable quality metrics.	work standards	Identify measurable process inputs and outputs.	consistent and perma-nent	Develop a cost-benefit measure for this telemedicine service.

Meso

	Man		Machine		Material		Method		Money
	0	0	0	0	0	0	0	0	0
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
0	is using this service.	0	is set up specifically for this service and is always available.	0	is linked with hospital information system (HIS).	0	is driven by someone that is formally and permanently appointed for this purpose.	0	does not rely on donor funds / seed funds.

Macro

	Man		Machine		Material		Method		Money
	0	0	0	0	0	0	0	0	0
Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement
0	:(a sufficiently large portion of) already used this service for most issues to be addressed.	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement	Current Maturity Level	Advice to aid in maturity improvement

Figure D.7: Recommendation report for a teleradiology service

D.2 Cohort Study of Teleradiology Cases

In South Africa most private hospital groups and some public hospital networks have fully functional teleradiological services. Nine teleradiology services that are amongst the 28 individual services which are available in the data warehouse of this study (refer to Figure D.8). Eight of these are from the public health sector and one is from the private health sector. Within the private health sector the PACSs are mostly fully integrated with the hospital information system as well as information systems from medical insurers. In some areas of the South African public health sectors, teleradiology services run successfully on a PACS. At other places less sophisticated teleradiology services are found, for example:

	1Man	2Machine	3Material	4Method	5Money
Teleradiology	**2.7**	**3.1**	**2.9**	**3.6**	**2.9**
Private Health Sector, PACS and RIS integrated	4.9	5.0	4.6	4.9	4.2
Public Health Sector, Digital CT scanner, Secondary to Tertiary hospital	4.4	4.3	3.2	4.3	3.9
Public Health Sector, Digital X-ray machine plus telemedicine workstation	2.2	3.1	2.6	3.6	3.1
Public Health Sector, Internal Service within Secondary hospital	2.9	3.0	2.9	3.2	3.6
Public Health Sector, Mobile phone driven, Bottom-up initiative	2.8	2.3	1.8	3.1	2.4
Public Health Sector, PACS for entire hospital complex, fully operational	2.8	2.3	2.8	3.1	3.2
Public Health Sector, PACS for entire hospital complex, pilot phase	1.8	2.9	2.9	3.4	2.0
Public Health Sector, Fax to Fax, top-down initiative	2.4	2.1	1.8	3.8	3.5
Public Hospital, Secondary to Tertiary, Fax to Fax, service not operational anymore	0.3	2.7	2.5	2.8	0.5

Figure D.8: Teleradiology services included in this cohort study

- "Hard-copy" radiological images (e.g. x-rays) are taken and then digitized by means of a scanner, from where it is uploaded to a PACS.
- "Hard-copy" radiological images (e.g. x-rays) are taken and then digitized by means of a scanner, from where it is e-mailed to specialist. The image is not archived.

- Medical officers take digital pictures of the "hard-copy" radiological image and SMS this image to specialist.

D.2.1 Who would be interested in this cohort study?

Providers of Teleradiology Technology and Infrastructure: What is the correlation (if any) between the maturity of teleradiology infrastructure and other capability areas? Which type of teleradiology process (capture or diagnose or react or transmit) typically exhibits the lowest level of maturity or the greatest variation among different services? Which devices are typically used for each of the processes?

Telemedicine co-ordinator (Person responsible for the planning and implementation of telemedicine services for a certain system, e.g. group of hospitals): Which capability areas typically exhibit the lowest level of maturity and the greatest variation among different services? What is the correlation between the maturity of mesolevel processes (which are typically the responsibility of such a person) and other capability areas.

Policy makers on provincial and governmental level: What are the maturity of the meso- and macrolevel processes?

Radiologists and Radiographers: What are the description and maturity of processes at the other end of a teleradiology service?

D.2.2 Overview of services included in this cohort

Figure D.8 shows the nine teleradiology services that were included in this study, together with their average maturity level per domain. It is significant that the private health sector teleradiology service exhibits a significantly higher level of maturity.

The aggregated maturity level per capability area (*Service*-dimension x *Domain*) are indicated in Figure D.9. Of all the microlevel processes, the maturity level of the *Capture* process is the highest. This can possibly attributed to the fact that the person (normally radiographer), technology, method and well as accounting procedure for the capture process are either the same or similar to the non-teleradiology service.

It can also be seen in both Figure D.8 and Figure D.8 that the *Methods* domain exhibits the highest level of maturity. Possible reasons for this become clearer later in this case study, when the detail descriptions of methods are considered in more detail.

D.2.2.1 Analysis of process maturity per type of process

In the next few sections, each type of process is viewed individually. All processes of a specific type are grouped together by means of *slide and dice* OLAP operations. The *fact* of the data warehouse is the maturity level (refer to Section 7.5.1). The *fact* for each domain of each of these processes is also indicated next to each process description. Pairwise correlation tests are performed to determine correlation in maturity level between the respective domains. Boxplots are also compiled to show the variation in maturity level for each domain.

D.2.2.2 Analysis of capture processes

Figure D.10 shows all of the *capture* type of processes from the cohort of tele-radiology services. A qualitative analysis of these can be of interest to stakeholders such as telemedicine co-ordinators, radiographers and radiologists to get an idea of the typical ways (technology and methods) in which radiology data are captured.

Providers of data capturing technology (e.g. X-ray machines, CT scanners etc.) might like to know which technology is currently used, the maturity thereof in terms of users and images (material) produced by this technology and entities responsible for operational costs.

The correlation matrix of the *capture* processes (Figure D.11) shows a relatively low pairwise correlation between the maturity levels of the *Money* domain and the other domains.

- $r_{\text{money-machine}} = 0.31$;
- $r_{\text{money-material}} = 0.16$;
- $r_{\text{money-method}} =$ no significant correlation.

	Man	Machine	Material	Method	Money
Capture	3.2	3.9	3.6	4.1	3.4
Diagnose	3.0	3.1	2.8	4.2	3.3
React	2.6	2.8	3.1	4.1	3.1
Transmit	2.6	3.3	3.1	3.6	2.5
Meso	2.8	2.7	2.1	2.8	2.9
Macro	2.3	2.4	1.8	1.7	2.3

Figure D.9: The average maturity in terms of the type of process

Radiographer (Level 1)	uses	x-ray, ultrasound device	to capture	x-ray/ ultrasound (digital format)	according to	standard radiogrophy work protocol	at the cost of the	DoH (employing instituion)	2.5	4	4	4	3.5
Radiographer	uses	CT Scanner	to capture	Digital radiographical image	according to	standard protocol	at the cost of the	referring hospital.	5	5	3	4.5	4.5
Radiographer (Level 1)	uses	x-ray/ultrasound device	to capture	x-ray/ultrasound (digital format)	according to	standard radiography protocol	at the cost of the	DoH (employing institution)	2	3	3	3.5	2
an administrator	uses	EHR system	to capture	patient folder	according to	EHR system protocol	at the cost of the	patient.	5	5	4.5	5	4
Radiographer	uses	digitial radiographic machine	to capture	a radiograph	according to	clinical standards	at the cost of the	patient.	5	5	4.5	5	4
Radiographer	uses	a computer workstation (PC)	to capture	a radiology health record	according to	system protocol of the specific x-ray	at the cost of the	the Provincial Department of Health	3	2	3	4	3.5
Medical Officer (Level 1)	uses	mobile phone (digital camera)	to capture	x-ray/ultrasound (digital image)	according to	own discretion	at the cost of the	DoH (employing institution)	2.5	2	2	1	4
Medical Officer (Level 1)	uses	traditional x-ray machine	to capture	x-ray (film)	according to	standard radiography procedure	at the cost of the	DoH (employing institution)	4	4.5	4.5	4.5	4
Radiographer (Level 1)	uses	x-ray device	to capture	x-ray (digital format)	according to	standard radiography protocol	at the cost of the	DoH (employing institution)	3	4	3.5	4.5	4
Radiographer (Level 1)	uses	x-ray device	to capture	x-ray (digital format)	according to	standard radiography protocol	at the cost of the	DoH (employing institution)	0	4	3.5	4.5	0

Figure D.10: Slice and dice for type of process = "capture"

	Man	**Machine**	**Material**	**Method**	**Money**
Man	1.00				
Machine	0.67	1.00			
Material	0.49	0.76	1.00		
Method	0.50	0.77	0.81	1.00	
Money	0.80	0.31	0.16	no corr.	1.00

Figure D.11: Pearson correlation matrix for "capture" processes

	Man	**Machine**	**Material**	**Method**	**Money**
Man	1.00				
Machine	0.79	1.00			
Material	0.55	0.76	1.00		
Method	0.63	0.77	0.81	1.00	
Money	0.67	0.54	0.28	0.18	1.00

Figure D.12: Pearson correlation matrix for "capture" processes (2)

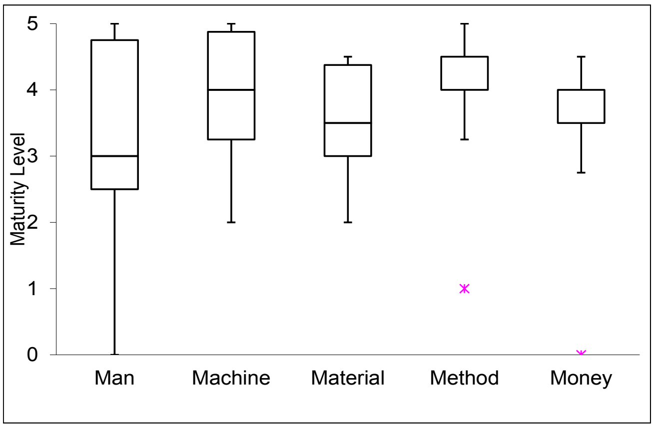


Figure D.13: Boxplots for "capture" processes

The exception is $r_{\text{money-man}}$, which is relatively high. The explanation is as follows: The last service listed on Figure D.10 represents a service which was operational until recently. However, when the seed funds dried up, it was not possible to pay the persons involved in the process. The technology, quality of material and methods are in place, but the service is not operational. When this last process is excluded from the correlation matrix, the affected pair-wise correlation coefficients all increase (refer to Figure D.12). This observation does not so much say something about teleradiology; it is rather an indication of the risk of misinterpretation when working with small sample sizes.

According to the boxplot of the maturity levels of the *capture* processes, the maturity of the users (*man*) has the greatest variation amongst different services, which indicates the need for a deliberate effort to educate and motivate all users concerning the teleradiology services.

D.2.2.3 Analysis of transmit processes

Each teleradiology service has at least two transmit processes, which is the reason why the list in Figure D.14 is the longest of all the *Slide and Dice*-views in this case study. The following observations are made:

- The transmission processes with the highest maturity levels were those that were delivered by the State Information Technology Association (SITA). This association is responsible for, amongst others, the internet connectivity of the public health sector. They are bound to specific service level agreements (SLAs).
- The processes involving fax transmissions resulted in the lowest maturity levels in terms of technology and material.
- Telemedicine co-ordinators and other policy makers should take note of the fact in the case of services that originated from a bottom-up initiative by healthcare workers, the cost incurred by the healthcare worker has most often not been considered. In this cohort case study, the service in which the mobile phone of the healthcare worker is used, is an example of such a study.

D.2.2.4 Analysis of diagnose processes

All of the *diagnose* processes included in this cohort study are listed in Figure D.17.

The variation of maturity levels for the *diagnose* processes (refer to boxplot, Figure D.18) is small for all domains, relative to the other processes (refer to tables D.13, D.26, D.22). A reason for this may be that these processes are homogenous in the sense that the radiologist (alias specialist) performs the diagnoses

Radiographer (Level 1)	uses	Telemedicine Workstation	to transmit	x-ray/ultrasound (digital format)	according to	mobile phone service provider	at the cost of the	Donor Funding	2.5	3	3	4	2
Radiologist (Level 2)	uses	department workstation (e-mail)	to transmit	radiological case (level 2 analysis)	according to	internet provider service protocol	at the cost of the	DoH (employing instituion)	2.5	3.5	3	4	3.5
Radiographer	uses	ISDN line	to transmit	DIgital radiographical image and madical info and motivation	according to	SITA SLA	at the cost of the	referring hospital.	5	5	3	5	4
Radiologist	uses	ISDN line (EMAIL)	to transmit	Diagnose report and advice.	according to	SITA SLA	at the cost of the	referring hospital.	5	4	3	5	3
Radiographer (Level 1)	uses	departmental workstation (PACS program)	to transmit	x-ray/ultrasound (diigital format)	according to	PACS protocol	at the cost of the	DoH (employing institution)	1.5	3	3.5	3	2
Radiologist (Level 2)	uses	departmental workstation (PACS program)	to transmit	radiological case analysis	according to	PACS protocol	at the cost of the	DoH (employing institution)	2	3	3.5	3	2
Specialist (Level 3)	uses	departmental workstation (PACS program)	to transmit	treatment recommendation/diagnosis	according to	PACS protocol	at the cost of the	DoH (employing institution)	2	3	4	3	2
Radiographer	uses	PACS/ Radiographic software package and internet service	to transmit	a radiograph together with patient folder	according to	SITA SLA	at the cost of the	patient.	4	5	5	4.5	5
An administrator	uses	radiographic software package and desktop computer	to transmit	report	according to	SITA SLA	at the cost of the	patient.	5	5	4.5	5	4
Radiologist	uses	the internet	to transmit	radiology data	according to	internet protocols	at the cost of the	the Provincial Department of Health	3	3	2.5	2	3.5
Medical Officer (Level 1)	uses	mobile phone (SMS/IM)	to transmit	radiography case	according to	mobile service provider protocol	at the cost of the	Medical Officer (Level 1)	4	3	2	4	0.5
Specialist (Level 2)	uses	mobile phone (SMS/IM)	to transmit	diagnoses / treatment recommendation	according to	mobile service provider protocol	at the cost of the	Specialist (Level 2)	2.5	3	2	4	0.5
Medical Officer (Level 1)	uses	fax machine (land line)	to transmit	x-ray (fax copy)	according to	Telkom service protocol	at the cost of the	DoH (employing institution)	2	2	1	4	2.5
Specialist (Level2)	uses	fax machine (land line)	to transmit	treatment recommendation	according to	Telkom service protocol	at the cost of the	DoH (employing institution)	2	1.5	1	4	4
Radiographer (Level 1)	uses	departemental workstation (PACS program)	to transmit	x-ray (digital format)	according to	PACS protocol	at the cost of the	DoH (employing institution)	3	3.5	4	4	3
Radiologist (Level 2)	uses	departemental workstation (PACS program)	to transmit	treatment recommendation / diagnosis	according to	PACS protocol	at the cost of the	DoH (employing institution)	3	3.5	3.5	3	3
Medical Officer (Level 1)	uses	computer work station with large screen in ward.	to transmit	radiological image and recommendation	according to	PACS protocol	at the cost of the	DoH (employing institution)	3	3	4	2.5	4
Radiographer (Level 1)	uses	departemental workstation (PACS program)	to transmit	x-ray (digital format)	according to	PACS protocol	at the cost of the	DoH (employing institution)	0	3.5	4	4	0

Figure D.14: Slice and dice for type of process = "transmit"

	Man	Machine	Material	Method	Money
Man	1.00				
Machine	0.73	1.00			
Material	0.12	0.66	1.00		
Method	0.70	0.54	0.36	1.00	
Money	0.45	0.44	0.20	0.36	1.00

Figure D.15: Pearson correlation matrix for "transmit" processes

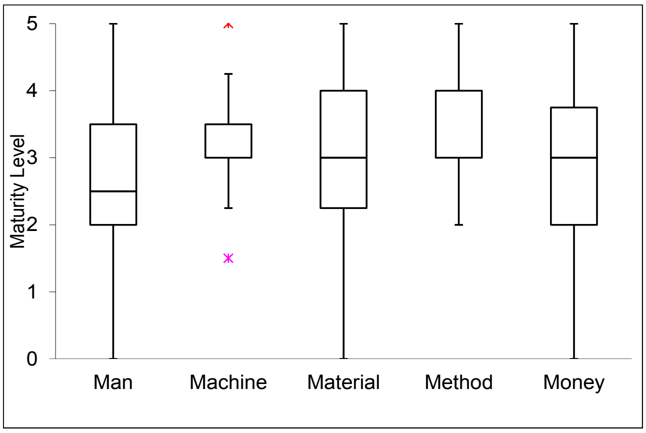


Figure D.16: Boxplots for "transmit" processes

according to a standard medical protocol, mostly at the cost of the employing institution. Within the context of Figure D.18, *machine* has the greatest variation in maturity, which aligns with the variation in devices used (Figure D.17).

The fact that these processes are relatively homogenous in description and maturity level, is also reflected by the fact that the correlation coefficients (Figure D.19) are also high, relative to the correlation coefficients for the *capture*, *transmit* and *react* processes.

D.2.2.5 Analysis of react processes

The type of persons who react to the transformed information varies significantly, as shown in the first column of Figure D.20. This may explain the variation in maturity level of the *man* domain (refer to Figure D.22).

According to correlation matrix (Figure D.21) there is little or no correlation between the maturity level of the *money* domain and the other domains. The correlation matrices for the other types of processes also show a relatively weak correlation between the *money* domain and other domains. It is possible that a cohort study

Radiologist (Level 2)	uses	department workstation (e-mail)	to diagnose	x-ray/ultrasound (digital format)	according to	standard medical protocol	at the cost of the	DoH (employing instituion)	2.5	3.5	2.5	4.5	3.5
Specialist (Level 3)	uses	department workstation (e-mail)	to diagnose	radiological case (level 2 analysis)	according to	standard medical protocol	at the cost of the	DoH (employing instituion)	2.5	3.5	2.5	4.5	4
Radiologist	uses	his own desktop computer and custom software	to diagnose	Diagnose report	according to	standard protocol	at the cost of the	receiving hospital.	5	4	3	3	4
Radiologist (Level 2)	uses	departmental workstation (PACS program)	to diagnose	radiological case	according to	standard medical protocol	at the cost of the	DoH (employing institution)	2	3	3	4.5	2.5
Specialist (Level 3)	uses	departmental workstation (PACS program)	to diagnose	radiological case analysis	according to	standard medical protocol	at the cost of the	DoH (employing institution)	2	3	3	4.5	2
Radiologist	uses	radiographic software package and desktop computer with specific monitor and dictation	to diagnose	radiograph and history	according to	expert knowledge/ experience and clinical protocol	at the cost of the	patient.	5	5	4.5	5	4
Radiologist	uses	radiographic software package and desktop computer and dictation technology	to diagnose	dicated report together with radiograph and history	according to	clinical standards	at the cost of the	patient.	5	5	3	5	4
Specialist	uses	radiology database	to diagnose	radiology data	according to	medical protocols	at the cost of the	the Provincial Department of Health	3	2	2	4	3.5
Specialist	uses	a computer workstation (PC)	to diagnose	the stored radiological patient record	according to	medical protocols	at the cost of the	the Provincial Department of Health	3	2	1	4	3.5
Specialist (Level 2)	uses	mobile phone (SMS/IM)	to diagnose	radiography case	according to	standard medical procedure	at the cost of the	DoH (employing institution)	2.5	2	3	4	4
Specialist (Level2)	uses	hardcopy (no electronic device)	to diagnose	radiography case	according to	standard medical procedure	at the cost of the	DoH (employing institution)	3	2	2	4.5	4
Radiologist (Level 2)	uses	departemental workstation (PACS program)	to diagnose	radiological case	according to	standard medical protocol	at the cost of the	DoH (employing institution)	3	3.5	0	4.5	4

Figure D.17: Slice and dice for type of process = "Diagnose"

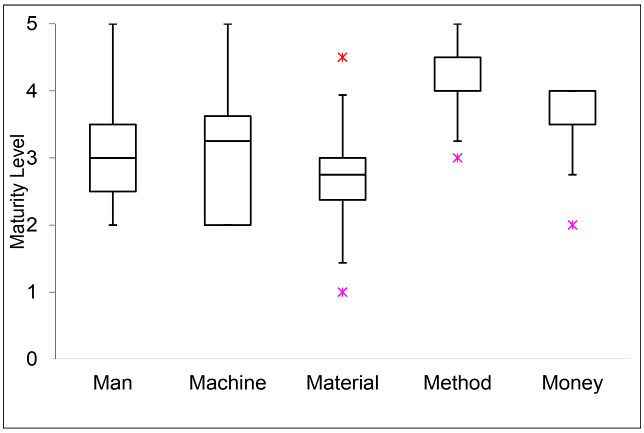


Figure D.18: Boxplots for "diagnose" processes

	Man	Machine	Material	Method	Money
Man	1.00				
Machine	0.70	1.00			
Material	0.62	0.78	1.00		
Method	0.34	0.47	0.41	1.00	
Money	0.77	0.37	0.21	0.45	1.00

Figure D.19: Pearson correlation matrix for "diagnose" processes

which includes more services from the private health sector, may show a higher correlation in this regard, as the public health sector is not so much driven by financial targets as the private health system.

Medical Officer (Level 2)	uses	Telemedicine Workstation	to react to	treatment recommendation / diagnosis	according to	standard medical protocol	at the cost of the	DoH (employing instituion)	1.5	3	3	4.5	4
Referring doctor	uses	his own desktop computer and	to react to	Diagnose report and advice	according to	standard protocol	at the cost of the	referring hospital.	5	4	3	3	3
Nurse (Level 1)	uses	departmental workstation (PACS program)	to react to	treatment recommendation/ diagnosis	according to	standard medical protocol	at the cost of the	DoH (employing institution)	1	3	4	4.5	2
Referring doctor	uses	report and physical examination	to react to	recommended diagnisis of the radiologist	according to	clinical standards	at the cost of the	patient.	5	5	4.5	5	4
Radio-logist	uses	radiology database	to react to	diagnosed pateint record	according to	system protocols	at the cost of the	the Provincial DoH	3	2.5	3	3	3.5
Medical Officer (Level 1)	uses	mobile phone (SMS/IM)	to react to	diagnoses / treatment recommendatio	according to	standard medical procedure	at the cost of the	DoH (employing institution)	2.5	2	2	4	4
Medical Officer (Level 1)	uses	hardcopy (no electronic device)	to react to	treatment recommendation	according to	standard medical procedure	at the cost of the	DoH (employing institution)	2	2	3	4.5	4
Medical Officer (Level 1)	uses	conventional hospital system	to react to	image and recommendation	according to	standard medical protocol	at the cost of the	DoH (employing institution)	3	2	2.5	4	3.5

Figure D.20: Slice and dice for type of process = "react"

	Man	Machine	Material	Method	Money
Man	1.00				
Machine	0.72	1.00			
Material	0.29	0.70	1.00		
Method	0.29	0.19	0.42	1.00	
Money	0.20	no corr.	no corr.	0.21	1.00

Figure D.21: Pearson correlation matrix for "react" processes

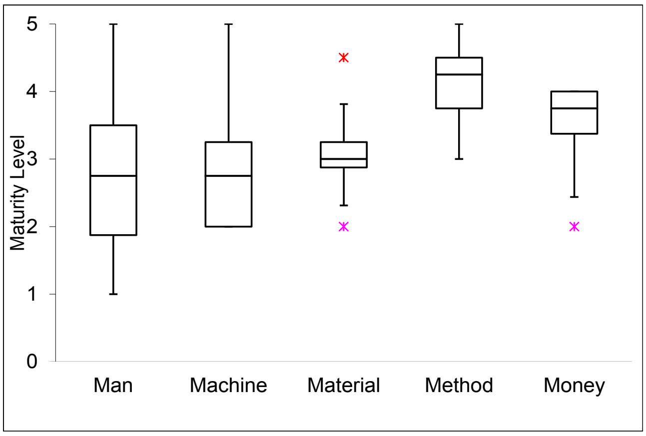


Figure D.22: Boxplots for "react" processes

	Man	Machine	Material	Method	Money
Man	1.00				
Machine	0.73	1.00			
Material	0.62	0.85	1.00		
Method	0.62	0.85	0.90	1.00	
Money	0.62	0.70	0.80	0.87	1.00

Figure D.23: Pearson correlation matrix for the mesolevel processes

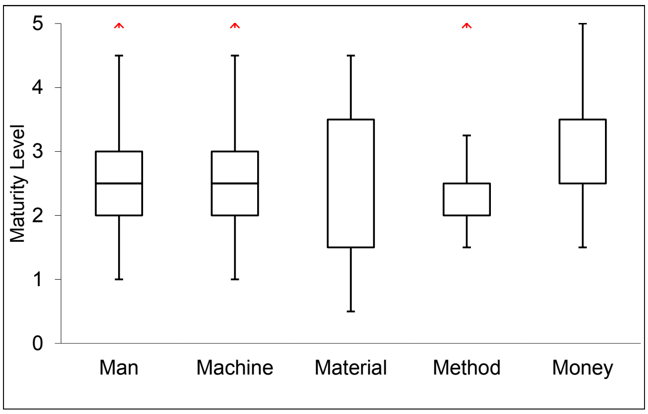


Figure D.24: Boxplots for the mesolevel processes

	Man	Machine	Material	Method	Money
Man	1.00				
Machine	0.73	1.00			
Material	0.62	0.85	1.00		
Method	0.62	0.85	0.90	1.00	
Money	0.62	0.70	0.80	0.87	1.00

Figure D.25: Pearson correlation matrix for the macrolevel processes

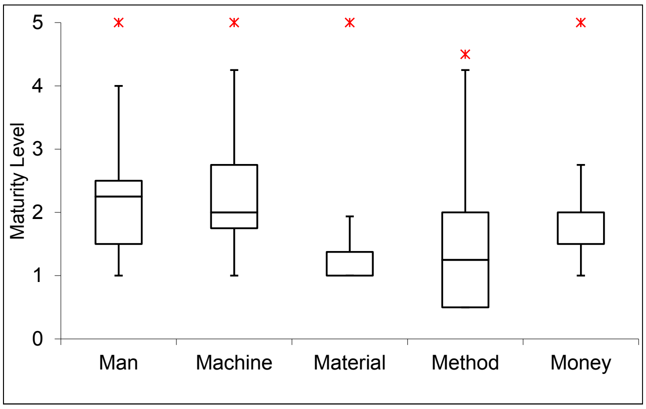


Figure D.26: Boxplots for the macrolevel processes

The boxplots of the macrolevel processes show a low median maturity level with one outlier per domain, reaching values of between 4.5 and 5. These outliers belong to the single service from the private health sector, while all of the other processes are from the public health sector. This does not come as a surprise and serve as validation of the TMSMM. The service which is represented by the outliers should be analyzed with the purpose of deriving best practices.

D.2.3 Significance to stakeholders

At the beginning of this case study four stakeholder groups were identified that may be interested in these cohort studies. These groups were taken into account throughout this case study. The possible value of a case study like this for each of these stakeholders is summarized below.

Providers of Teleradiology Technology and Infrastructure: Research on telemedicine most often focusses on cutting technology and best practices or, on the other hand, on service failures and possible reasons for these. Cohort studies like these provide a simple inventory of current technology and practices, which is otherwise not known.

Service Dimension (Slice for Domain = "Material")	
Analyse	
dictated report together with radiograph and history	4.5
radiological case	3
radiology data	3
x-ray/ultrasound (digital format)	2.5
Capture	
a radiograph	5
a radiology health record	3
patient folder	5
x-ray (digital format)	3.5
x-ray (digital image)	2
x-ray (film)	4.5
x-ray/ultrasound (digital format)	4
x-ray/ultrasound (digital image)	2
x-ray/ultrasound (diigital format)	3
Diagnose	
radiograph and history	4.5
radiography case	1
radiography case	2
radiological case	2.5
radiological case (level 2 analysis)	2.5
radiological case analysis	3
the stored radiological patient record	3
React	
diagnosed pateint record	3
diagnoses / treatment recommendation	2
image and recommendation	2.5
recommended diagnisis of the radiologist	4.5
treatment recommendation	3
treatment recommendation / diagnosis	2.5
treatment recommendation/diagnosis	3.75
Transmit Data	
a radiograph together with patient folder	5
diagnoses / treatment recommendation	2
patient medical data (recorded in patient file)	4
radiography case	2
radiological case (level 2 analysis)	3
radiological case analysis	3.5
radiological image and recommendation	4
radiology data	2.5
report	5
treatment recommendation	1
treatment recommendation / diagnosis	3.25
treatment recommendation/diagnosis	3.5
x-ray (digital format)	4
x-ray (digital image)	2.5
x-ray (fax copy)	5
x-ray/ultrasound (digital format)	1
x-ray/ultrasound (diigital format)	2

Figure D.27: slice domain

Telemedicine co-ordinator (Person responsible for the planning and implementation of telemedicine services for a certain system, e.g. group of hospitals): The maturity of the users (*man*) has the greatest variation amongst different services. A deliberate effort is necessary to narrow th to educate and motivate all users concerning the teleradiology services.

Policy makers on provincial and governmental level: These stakeholders should take note of the fact in the case of services that originated from a bottom-up initiative by healthcare workers, the cost incurred by the healthcare worker has most often not been considered.

Radiologists and Radiographers: Generally, the same medical protocols applies to the capturing and diagnosing process, than would have been the case if the service was not delivered over a distance.

D.2.4 Other observations that confirmed the validity of the TMSMM

- According to correlation matrix (Figure D.21 there is little or no correlation between the maturity level of the *money* domain and the other domains. The correlation matrices for the other types of processes also show relative low correlation between the *money* domain and other domains. With the exception of one service, all of the services in this cohort study are from the public health sector. The financial maturity of a service is of lesser concern in the public health sector than the maturity of the users, technology, information and methods.

- The *methods* domain exhibits that highest level of maturity, which makes sense in a system adherence to procedures and protocol is more important than the motivation of person, the sophistication of technology or the financial sustainability of processes.

D.3 Cohort Study of Telemedicine Services of a Specific Hospital Network

For purposes of this cohort study a hospital network is considered to be a tertiary or secondary hospital, which is connected to a few clinics. This is also referred to as *hub-and-spokes*. Amongst the 28 telemedicine services listed in Section D.1 are 24 services from a total of nine such hospital networks.

D.3.1 Stakeholders

Who would be interested in this cohort study?

Telemedicine co-ordinator of the particular hospital complex: Which capability areas typically exhibit the lowest level of maturity and the greatest variation among different services? What is the correlation between the maturity of meso-level processes (which are typically the responsibility of such a person) and other capability areas?

Managers (overall, clinical and technical) at the tersiary hospital as well as secondary hospitals and primary health care clinics: Which type of process (capture/ diagnose/ transmit) exhibits the lowest / highest level of maturity? The chain is as strong the weakest link. This information will help them to focus on areas for improvement. Which domains need attention on meso and macro level?

Sponsors of pilot projects: What is the level of maturity of this service along all domains and type of processes, relative to the other. What influence could the meso and macro level enviroment have on the maturity of the services.

Telemedicine co-ordinators of other hospital complexes: In which areas do this hospital complex exhibit high maturity? This can guide towards the identification and adoption of best practices.

Policy makers on provincial and governmental level: What is the maturity level of the macro-level processes? How can it be improved?

This cohort study include seven telemedicine service from a certain hospital complex, which is called hospital complex C for purposes of this study. The average maturity level for this cohort, relative to the other networks are indicated in Figure D.28.

The seven services of this hospital complex are listed in Figure D.2. Five of these services were implemented in a top-down manner as intiative from the management

	Man	Machine	Material	Method	Money
A	2.81	2.29	2.79	3.07	3.21
Ad Hoc	1.00	2.50	2.54	1.91	1.55
B	2.24	2.14	1.60	3.33	2.58
C	3.22	2.69	2.33	2.71	2.54
D	2.18	2.30	2.03	3.14	3.12
E	4.55	4.67	4.67	4.72	4.67
F	2.18	2.11	1.46	3.31	2.98
G	2.33	2.31	1.75	3.29	2.70
H	2.79	2.87	2.75	3.00	3.58
I	1.61	2.24	1.79	3.01	2.33

Figure D.28: Summary of service maturity of the nine networks

of the hospital network. The two services that were developed as a bottom-up initiative of specialist who share medical images via SMS are the following:

- The teledermatology services
- The ophthalmology service

The maturity level difference between the top-down and bottom-up services can clearly be seen in Figure D.2. These services are effective although the users are not specifically trained and the technology are not specifically developed for this purpose. The telemedicine co-ordinator and hospital management could consider to invest time and effort to enhance the maturity of these services through a top-down approach and then to replicate the service in other contexts.

D.3.2 Analysis of process maturity per type of process

In the next few sections, each type of process is viewed individually. All processes of a specific type are grouped together by means of *slide and dice* OLAP operations. The *fact* of the data warehouse is the quantitative value of the maturity level as derived from the capability statements. The *fact* for each domain of each of these processes is also indicated next to each process description. Pairwise correlation tests are performed to determine correlation in maturity level between the respective domains. Boxplots are also compiled to show the variation in maturity level for each domain.

	1Man	2Machine	3Material	4Method	5Money
C	**2.81**	**2.69**	**2.33**	**2.71**	**2.54**
Telecardiology at hospital C	2.94	3.43	2.64	2.64	2.86
Teleconsultation (pediatrics) at hospital C	3.44	1.93	2.29	2.64	2.79
Teleconsultation (post-operation) at hospital C	2.88	1.93	2.29	2.64	2.64
Teledermatology at hospital C	1.69	2.29	2.79	2.93	2.07
Tele-education at hospital C	3.21	4.17	2.33	2.92	2.92
Teleopthalmology at hospital C	1.75	1.57	1.29	1.57	1.21
Teleradiology at hospital C	3.81	3.71	2.71	3.64	3.36

Table D.2: Telemedicine services included in this cohort study

	1Man	2Machine	3Material	4Method	5Money
C	**2.81**	**2.69**	**2.33**	**2.71**	**2.54**
Analyse	4.50	5.00	3.00	3.00	4.50
Capture	3.36	3.14	2.57	2.21	2.36
Diagnose	3.42	2.00	2.17	3.00	3.33
React	3.75	2.92	2.67	3.83	3.17
Transmit Data	3.61	2.86	2.79	2.93	2.43
xMeso	1.32	3.50	2.21	3.07	3.21
xMacro	2.07	1.14	1.07	1.14	0.79

Figure D.29: Maturity of type of service in cohort study

	1Man	2Machine	3Material	4Method	5Money
C	**2.81**	**2.69**	**2.33**	**2.71**	**2.54**
Analyse	**4.50**	**5.00**	**3.00**	**3.00**	**4.50**
Capture	**3.36**	**3.14**	**2.57**	**2.21**	**2.36**
Medical Officer in Children's ward present case to pediatrician	4.50	3.00	2.00	0.50	1.50
Medical Officer take picture of retina with own mobile phone.	2.00	0.50	1.00	1.00	0.50
Medical Officer takes digital image of skin.	0.50	0.50	2.00	2.00	2.00
Nurse present post operative case to surgeon	3.00	3.00	2.00	0.50	1.50
Radiograper takes paper-ECG	4.50	5.00	5.00	4.00	4.00
The lecturer presents a lecture infront of the teleconferencing e	4.00	5.00	3.00	3.00	2.50
The radiographer take a CT scan.	5.00	5.00	3.00	4.50	4.50
Diagnose	**3.42**	**2.00**	**2.17**	**3.00**	**3.33**
Cardiologist base diagnosis on faxed ECG	4.00	3.00	2.00	3.00	3.00
Dermatologist diagnose digital image	2.00	0.50	2.00	2.00	2.00
Radiologist diagnose based on CT scan and other medical inform	5.00	4.00	3.00	3.00	4.00
The opthalmologist analyze the picture of the retina	2.00	0.50	2.00	3.00	3.00
The pediatrician considers case	4.50	2.00	2.00	3.50	4.00
The surgeon considers case	3.00	2.00	2.00	3.50	4.00
React	**3.75**	**2.92**	**2.67**	**3.83**	**3.17**
Medical Officer	4.00	2.00	3.00	4.00	2.00
Medical Officer administer treatment	4.00	4.00	2.00	4.00	3.00
The Medical Officer consider advice of opthalmologist to prescr	2.00	2.50	2.00	4.00	3.00
The medical officer react to advice	3.75	2.50	3.00	4.00	4.00
The referring doctor considers radiologist's advice to suggest tre	5.00	4.00	3.00	3.00	3.00
Transmit Data	**3.61**	**2.86**	**2.79**	**2.93**	**2.43**
Cardiologist communicate diagnosis and advice over telephone	2.50	2.50	3.00	2.00	3.00
Dermatologist send diagnosis and advice	2.00	4.50	3.50	3.00	2.00
Medical Officer transmits digital image over ISDN-line.	2.00	4.50	3.00	4.50	2.00
Radiographer faxes paper-ECG	3.00	4.00	3.00	2.00	3.00
Real time video is transmitted	4.50	0.50	1.50	1.00	1.50
The CT scan is tranmitted per ISDN line	5.00	5.00	3.00	5.00	4.00
The lecture is transmitted in real time.	5.00	5.00	3.00	4.00	2.50
The Medical Officer SMS the picture of the retina to the opthalm	2.00	2.00	1.50	1.00	0.50
The opthalmologist SMS diagnosis and advice	2.00	2.00	1.50	1.00	0.50
The pediatrician communicates diagnosis and advice	4.50	0.50	4.50	3.50	4.00
The radiologist send diagnoses and advice via e-mail.	5.00	4.00	3.00	5.00	3.00
The registratrar's response is transmitted in real-time.	4.00	4.50	2.50	4.50	2.50

Figure D.30: Maturity of type of service: Drill-down for process

D.3.2.1 Analysis of capture processes

Figure D.33 shows all of the *capture* type of processes from the cohort of the services from this complex. A qualitative analysis of these can be of interest to stakeholders such as telemedicine co-ordinators, hospital managers and regional decision makers to get an idea of the typical ways (technology and methods) in which radiology data are captured.

	Man	**Machine**	**Material**	**Method**	**Money**
Man	1.00				
Machine	0.89	1.00			
Material	0.57	0.78	1.00		
Method	0.45	0.66	0.76	1.00	
Money	0.60	0.77	0.83	0.93	1.00

Figure D.31: Pearson correlation matrix for "capture" processes

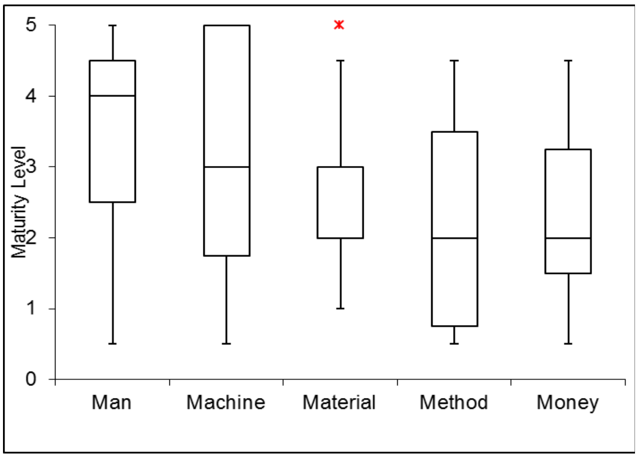


Figure D.32: Boxplots for "capture" processes

The correlation matrix of the *capture* processes (Figure D.11) shows a relatively low pairwise correlation between the maturity levels of the *Money* domain and the other domains.

- $r_{\text{money-machine}} = 0.31$;
- $r_{\text{money-material}} = 0.16$;
- $r_{\text{money-method}}$ = no significant correlation.

Radiographer	uses	CT Scanner	to capture	Digital radiographical image	according to	standard protocol	at the cost of the	referring hospital.	5	5	3	4.5	4.5
Medical Officer	uses	TM workstation camera	to capture	digital image of skin	according to	own discresion	at the cost of the	referring hospital.	0.5	0.5	2	2	2
Radiographer	uses	ECG-machine	to capture	ECG	according to	standard medical hospital	at the cost of the	referring hospital.	4.5	5	5	4	4
The medical officer	uses	his own mobile phone	to capture	digital image of eye	according to	own discresion	at the cost of the	the medical officer.	2	0.5	1	1	0.5
The medical officer in children's ward	uses	teleconferencing equipment	to capture	real time video to present pediatric case	according to	a not yet standard protocol	at the cost of the	clinic / secondary hospital.	4.5	3	2	0.5	1.5
Nurse	uses	teleconferencing equipment	to capture	real time video to present post surgery case.	according to	a not yet standard protocol	at the cost of the	clinic / secondary hospital.	3	3	2	0.5	1.5
Lecturer	uses	video-conferencing	to capture	real time video of lecture	according to	standard lecturing practices.	at the cost of the	sending institution.	4	5	3	3	2.5

Figure D.33: Slice and dice for type of process = "capture"

D.3.2.2 Analysis of transmit processes

The following observations are based on Figure ?? and Figure D.34 are used as basis for analysis.

This specific hospital network relies strongly on ISDN-line connectivity. It is the same ISDN network used for all services in this network and it is part of the standard service delivery of the State Information Technology Agency (SITA). Hence, it can be expected that this for this particular capability are the same maturity level will apply in all cases involving an ISDN line. For all processes the maturity in the case of ISDN were gauged at 3 (with the exception of two instances that measures 3.5 and 2.5 respectively). This variation possibly indicates that the maturity assessment procedure has a level of subjectivity.

It is clear that as this particular hospital the use of mobile technology and connectivity is not formally supported. However, as few users make use of their own mobile phone and service provider and other initiatives aims at using this technology. It is suggested that the hospital management investigate the feasibility of investing in mobile phone technology.

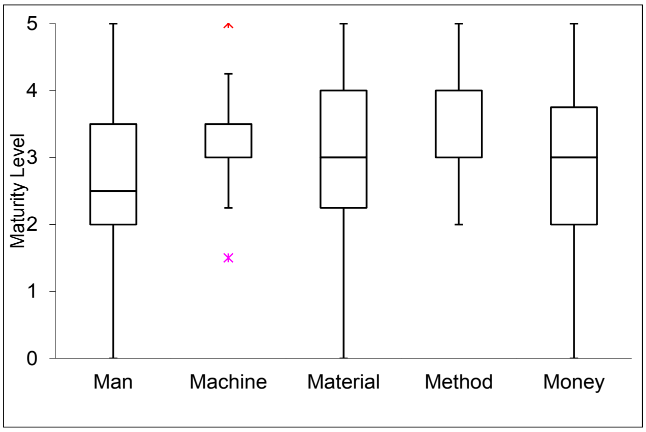


Figure D.34: Boxplots for "transmit" processes

Radiographer	uses	ISDN line	to transmit	DIgital radiographical image and madical info and motivation	according to	SITA SLA	at the cost of the	referring hospital.	5	5	3	5	4
Radiologist	uses	ISDN line (EMAIL)	to transmit	Diagnose report and advice.	according to	SITA SLA	at the cost of the	referring hospital.	5	4	3	5	3
Dermatologist	uses	ISDN-line	to transmit	report with diagnosis and advice	according to	TM web-interface protocol.	at the cost of the	receiving hospital.	2	4.5	3.5	3	2
Medical Officer	uses	ISDN-line	to transmit	digital image of skin and patient ID	according to	SITA service	at the cost of the	referring hospital.	2	4.5	3	4.5	2
Cardiologist	uses	Landline Telephone	to transmit	diagnosis and advice	according to	normal telephone procedure.	at the cost of the	receiving hospital.	2.5	2.5	3	2	3
Radiographer	uses	Fax-machine	to transmit	ECG	according to	normal fax procedure.	at the cost of the	referring hospital.	3	4	3	2	3
The medical officer	uses	his own network provider	to transmit	digital image of eye and additional information	according to	mobile network service provider	at the cost of the	the medical officer.	2	2	1.5	1	0.5
The opthalmologist	uses	his own mobile phone	to transmit	text message with diagnosis and advice	according to	mobile network service provider	at the cost of the	the opthalmologist.	2	2	1.5	1	0.5
The ward-round technical assistant	uses	not yet considered	to transmit	real time video to present pediatric case	according to	a not yet standard protocol	at the cost of the	clinic / secondary hospital.	4.5	0.5	1.5	1	1.5
The pediatrician	uses	the 3G / WiFi connection (not yet decided)	to transmit	real time video recording of advice	according to	transmission protocol	at the cost of the	the tertiary hospital.	4.5	0.5	4.5	3.5	4
The ward-round technical assistant	uses	not yet considered	to transmit	real time video to present post surgery case.	according to	a not yet standard protocol	at the cost of the	clinic / secondary hospital.	4.5	0.5	1.5	1	1.5
The pediatrician	uses	the 3G / WiFi connection (not yet decided)	to transmit	real time video recording of advice	according to	transmission protocol	at the cost of the	the tertiary hospital.	4.5	0.5	4.5	3.5	4
Facilitator	uses	ISDN	to transmit	real time video of lecture	according to	SITA SLA	at the cost of the	both institutions (shared).	5	5	3	4	2.5
Facilitator	uses	ISDN	to transmit	real time video of lecture	according to	standard	at the cost of the	both institutions (shared)	4	4.5	2.5	4.5	2.5

Figure D.35: Slice and dice for type of process = "transmit"

D.3.2.3 Analysis of diagnose processes

All of the *diagnose* processes included in this cohort study are listed in Figure D.17. The correlation between the different domains as well as boxplots are indicated respectively by Figure D.36 and Figure D.37.

Compared to boxplots of the other micro-level processes, the variation in maturity levels for the material and method domains are relatively small. This can possibly be attributed to the fact that a standard diagnosing protocol are followed based on standard information and images, irrespective the the technology use. The fact that the average maturity of the man-domain is relatively high can possibly be attributed to this fact that this particular micro-level process, diagnose, is the core responsibility of the user.

	Man	Machine	Material	Method	Money
Man	1.00				
Machine	0.86	1.00			
Material	0.65	0.84	1.00		
Method	0.47	0.30	0.00	1.00	
Money	0.74	0.74	0.59	0.77	1.00

Figure D.36: Pearson correlation matrix for "diagnose" processes

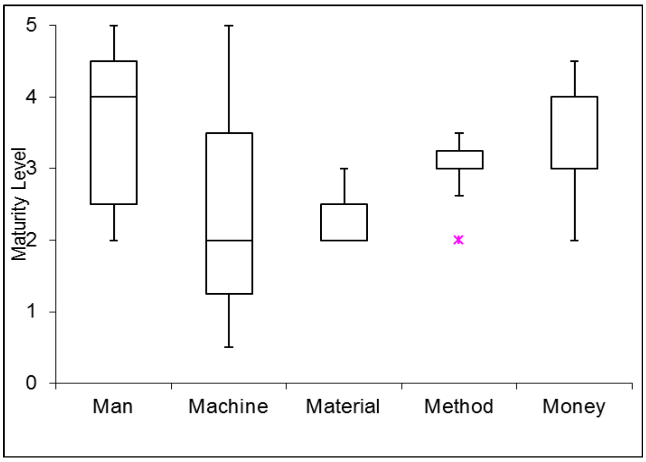


Figure D.37: Boxplots for "diagnose" processes

Radiologist	uses	his own desktop computer and custom software	to diagnose	Diagnose report	according to	standard protocol	at the cost of the	receiving hospital.	5	4	3	3	4
Dermatologist	uses	TM workstation screen	to diagnose	digital image of skin and patient data from HIS	according to	standard medical protocol	at the cost of the	receiving hospital.	2	0.5	2	2	2
Cardiologist	uses	Fax-machine	to diagnose	faxed ECG	according to	standard medical protocol	at the cost of the	referring hospital.	4	3	2	3	3
The opthalmologist	uses	his own mobile phone	to diagnose	digital image of eye and additional information	according to	standard diagnosing protocol	at the cost of the	the hospital.	2	0.5	2	3	3
The pediatrician	uses	his official iPad (application not yet decided)	to diagnose	the pediatric case presented in real time video	according to	standard medical protocol	at the cost of the	tertiary hospital.	4.5	2	2	3.5	4
The surgeon	uses	his official iPad (application not yet decided)	to diagnose	the post surgery case presented in real time video	according to	standard medical protocol	at the cost of the	tertiary hospital.	3	2	2	3.5	4
Registrars	uses	video-conferencing	to diagnose	content of lecture	according to	standard	at the cost of the	receiving institution.	4.5	5	3	3	4.5

Figure D.38: Slice and dice for type of process = "diagnose"

D.3.2.4 Analysis of react processes

The react-process is and essential part of the telemedicine service, although is mostly does not rely on information and communication technology. In most cases the same "man", "machine", "material", "method" and "money" is used as in the case of non-telemedicine services. This may be the reason why there is a relative small maturity level variation for most domains. The hospital management may consider to investigate the possibility of exploiting ICT for purposes of this micro-level process.

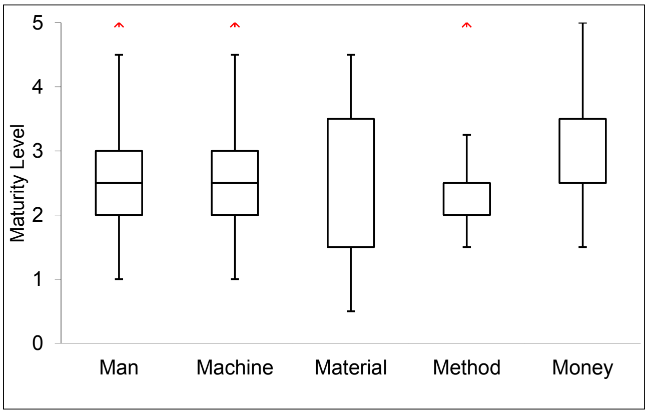


Figure D.39: Boxplots for "react" processes

Referring doctor	uses	his own desktop computer and custom software	to react to	Diagnose report and advice (confirmation)	according to	standard protocol	at the cost of the	referring hospital.	5	4	3	3	3
Medical Officer	uses	no specific technological device	to react to	diagnosis and advice	according to	standard medical protocol	at the cost of the	referring hospital.	4	2	3	4	2
Medical Officer	uses	conventional medical equipment	to react to	diagnosis and advice	according to	standard medical protocol	at the cost of the	referring hospital.	4	4	2	4	3
The medical officer	uses	not a specific technological device	to react to	SMS with advice from opthalmologist	according to	standard medical protocol	at the cost of the	the hospital.	2	2.5	2	4	3
The medical officer	uses	not a specific technological device	to react to	diagnosis and advice	according to	standard medical protocol	at the cost of the	clinic / secondary hospital.	4.5	2.5	3	4	4
The nurse	uses	not a specific technological device	to react to	diagnosis and advice	according to	standard medical protocol	at the cost of the	clinic / secondary hospital.	3	2.5	3	4	4

Figure D.40: Slice and sice for type of Process = "react"

D.3.3 Significance to stakeholders

At the beginning of this case study four stakeholder groups were identified that may be interested in these cohort studies. These groups were taken into account throughout this case study. The possible value of a case study like this for all of these stakeholders are summarized below.

Telemedicine co-ordinator of the specific hospital network:

Managers (overall, clinical and technical) at the central hospital as well as secondary hospitals and healthcare clinics within the network: When a new telemedicine service is planned, it is good to consider the levels of maturity at the hospital and clinics that will be part of this new service.

Potential sponsors of pilot projects: Companies, for example mobile phone service providers, often sponsor telemedicine experiments and pilot projects.

Telemedicine co-ordinators of other hospital networks may be interested in similar analysis for benchmarking purposes.

Decision-makers at provincial and governmental level: Figure D.28 shows the roll-up view of average maturity per hospital network. Decision-makers can identify hospital networks with high maturity in certain capability areas with the purpose of identifying best practices. This figure also indicates areas in terms of hospital complex, but also capability areas that need particular attention.

Appendix E

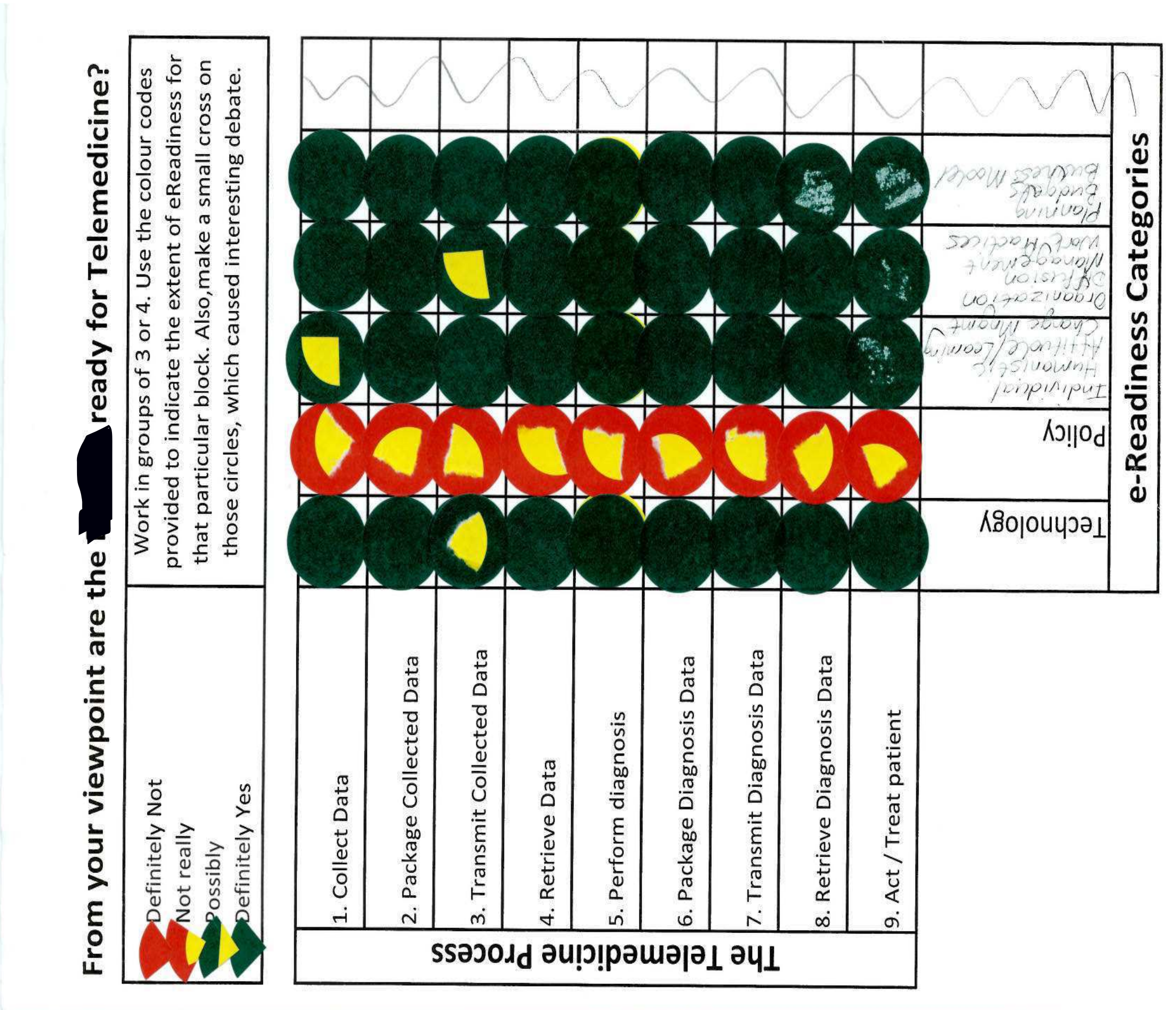
Workshop Worksheets

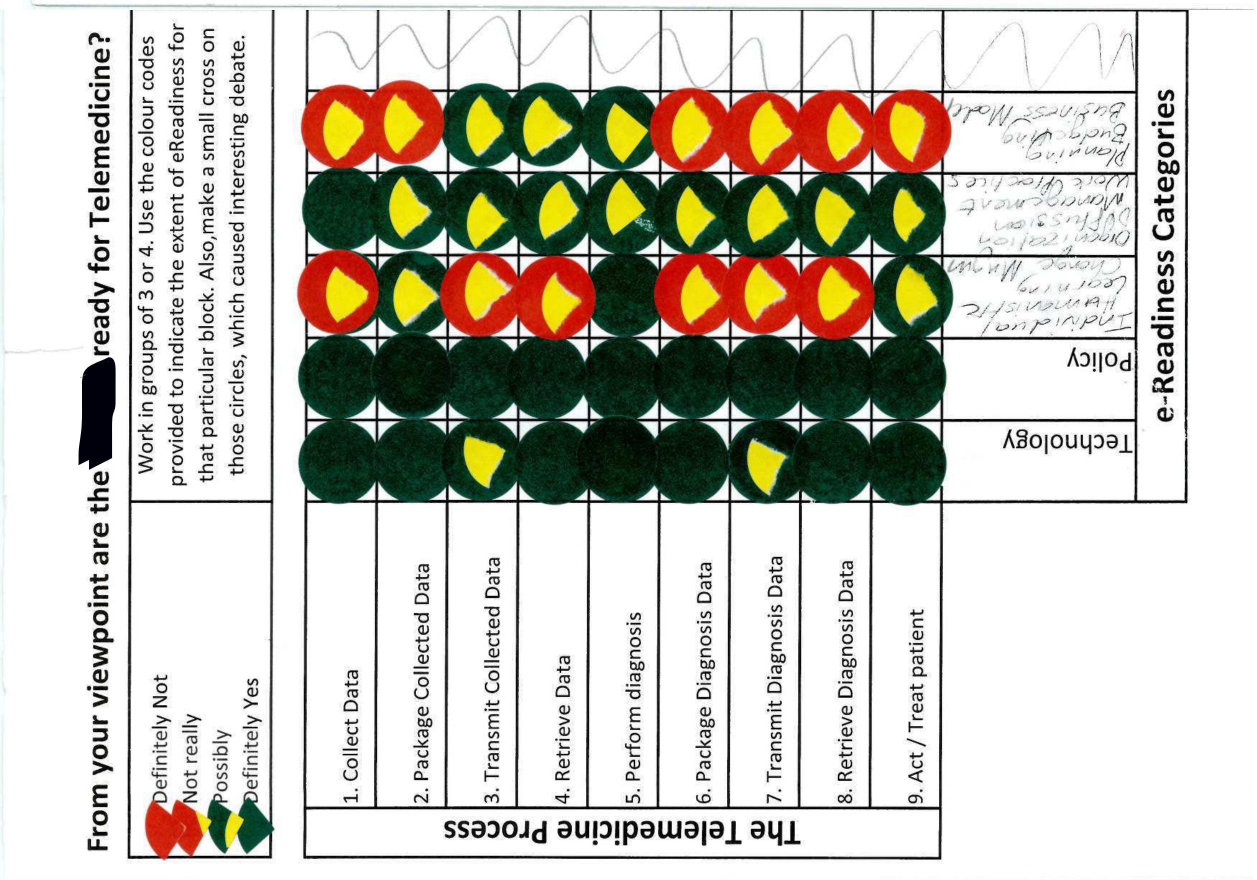
Between June 2011 and December 2011, a series of workshops was held in South Africa. Representatives included healthcare workers (e.g. specialists, radiologists, radiographers and nurses), as well as persons responsible for the development, implementation and maintenance of hospital information and communication technology (ICT). Most of the workshop participants were from the public health sector.

The first day of these workshops was used to educate representatives about telemedicine. On the second day, workshop delegates used earlier versions of the TMSMM to describe and assess telemedicine services within their context. In doing so, they gained an appreciation for all of the aspects that determine telemedicine success and learned from each other about the clinical and technical detail concerning their telemedicine service.

Some worksheets that were produced during these workshops are included in this appendix. Unfortunately, the worksheets for the first workshop was not archived. Although the quality of these worksheets are not acceptable for presenation of detailed information, these worksheets are included to show evidence of the methodology followed:

1. The worksheets were prepared before the commencement of the workshop. These worksheets were based on the most current version of the TMSMM.
2. During the second and third workshop contributed to the formulation of the domain dimension, through brainstorming and discussion. At that stage domain specifica maturity indicators was not provided.
3. During the fourth workshop, the delegates did not contributed to the definition of the domain-specific maturity scales, rather than the domain dimension.


From your viewpoint are the [redacted] ready for Telemedicine?
Definitely Not
Not really
Possibly
Definitely Yes
Work in groups of 3 or 4. Use the colour codes provided to indicate the extent of eReadiness for that particular block. Also, make a small cross on those circles, which caused interesting debate.
The Telemedicine Process
1. Collect Data
2. Package Collected Data
3. Transmit Collected Data
4. Retrieve Data
5. Perform diagnosis
6. Package Diagnosis Data
7. Transmit Diagnosis Data
8. Retrieve Diagnosis Data
9. Act / Treat patient
Technology
Policy
e-Readiness Categories


From your viewpoint are the [redacted] ready for Telemedicine?
Definitely Not
Not really
Possibly
Definitely Yes
Work in groups of 3 or 4. Use the colour codes provided to indicate the extent of eReadiness for that particular block. Also, make a small cross on those circles, which caused interesting debate.
The Telemedicine Process
1. Collect Data
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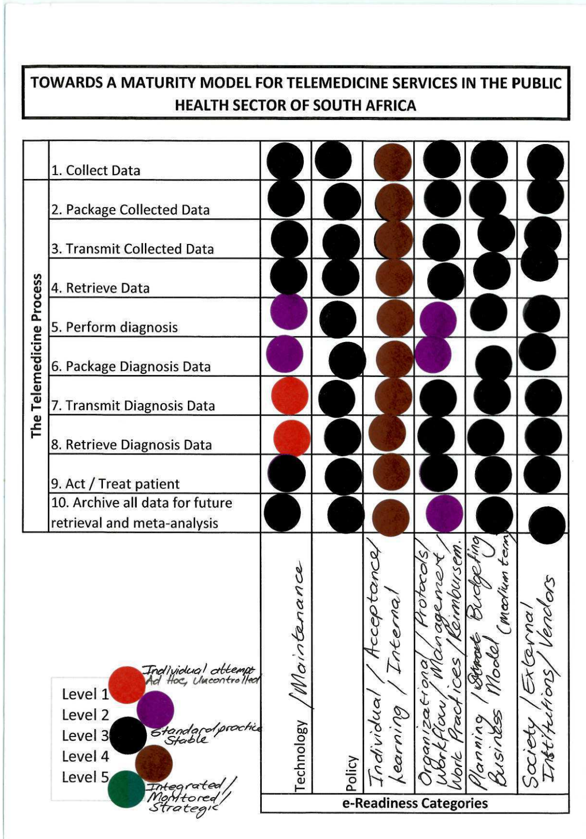
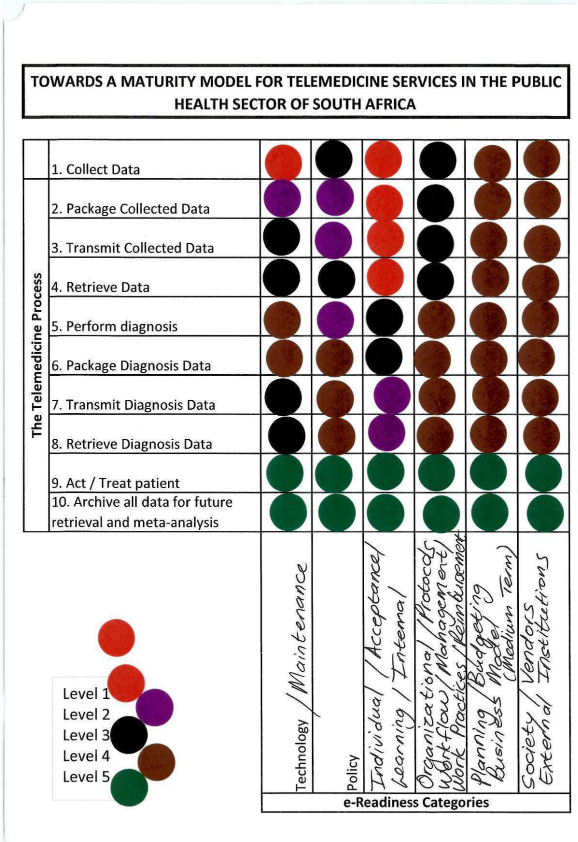
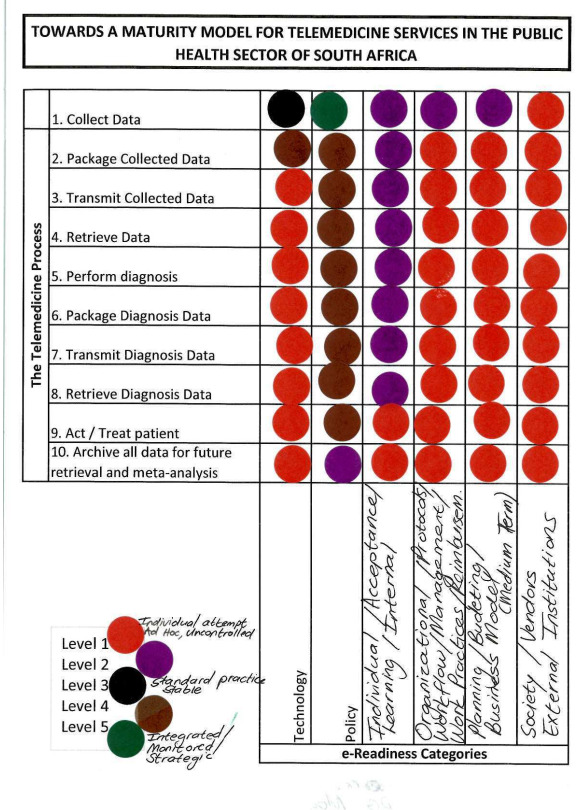
5. Perform diagnosis
6. Package Diagnosis Data
7. Transmit Diagnosis Data
8. Retrieve Diagnosis Data
9. Act / Treat patient
Technology
Policy
e-Readiness Categories


TOWARDS A MATURITY MODEL FOR TELEMEDICINE SERVICES IN THE PUBLIC HEALTH SECTOR OF SOUTH AFRICA
The Telemedicine Process
1. Collect Data
2. Package Collected Data
3. Transmit Collected Data
4. Retrieve Data
5. Perform diagnosis
6. Package Diagnosis Data
7. Transmit Diagnosis Data
8. Retrieve Diagnosis Data
9. Act / Treat patient
10. Archive all data for future retrieval and meta-analysis
Level 1
Level 2
Level 3
Level 4
Level 5
Individual attempt Ad Hoc, Uncontrolled
Standard practice Stable
Integrated/ Monitored/ Strategic
Technology / Maintenance
Policy
Individual / Acceptance / Learning / Internal
Organizational / Protocols / Workflow / Management / Work Practices / Reimbursem.
Planning / Budgeting / Business Model (medium term)
Society / External / Institutions / Vendors
e-Readiness Categories


TOWARDS A MATURITY MODEL FOR TELEMEDICINE SERVICES IN THE PUBLIC HEALTH SECTOR OF SOUTH AFRICA
The Telemedicine Process
1. Collect Data
2. Package Collected Data
3. Transmit Collected Data
4. Retrieve Data
5. Perform diagnosis
6. Package Diagnosis Data
7. Transmit Diagnosis Data
8. Retrieve Diagnosis Data
9. Act / Treat patient
10. Archive all data for future retrieval and meta-analysis
Level 1
Level 2
Level 3
Level 4
Level 5
Technology / Maintenance
Policy
Individual / Acceptance / Learning / Internal
Organizational / Protocols / Workflow / Management / Work Practices / Reimbursement
Planning / Budgeting / Business Model (Medium Term)
Society / Vendors / External / Institutions
e-Readiness Categories


TOWARDS A MATURITY MODEL FOR TELEMEDICINE SERVICES IN THE PUBLIC HEALTH SECTOR OF SOUTH AFRICA
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Level 1
Level 2
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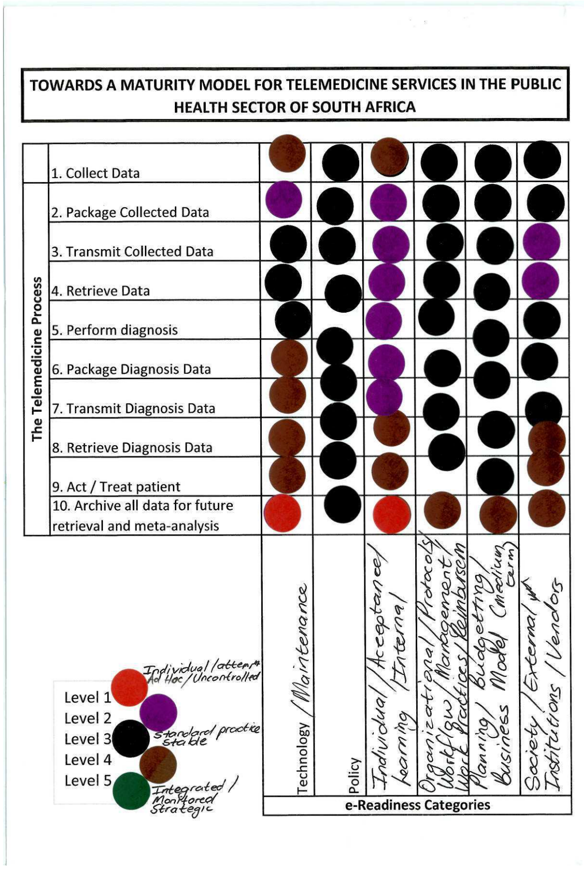
Level 4
Level 5
Individual attempt Ad Hoc, Uncontrolled
Standard practice Stable
Integrated/ Monitored/ Strategic
Technology
Policy
Individual / Acceptance / Learning / Internal
Organizational / Protocols / Workflow / Management / Work Practices / Reimbursem.
Planning / Budgeting / Business Model / (Medium Term)
Society / Vendors / External / Institutions
e-Readiness Categories


TOWARDS A MATURITY MODEL FOR TELEMEDICINE SERVICES IN THE PUBLIC HEALTH SECTOR OF SOUTH AFRICA
The Telemedicine Process
1. Collect Data
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3. Transmit Collected Data
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Level 1
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Level 3
Level 4
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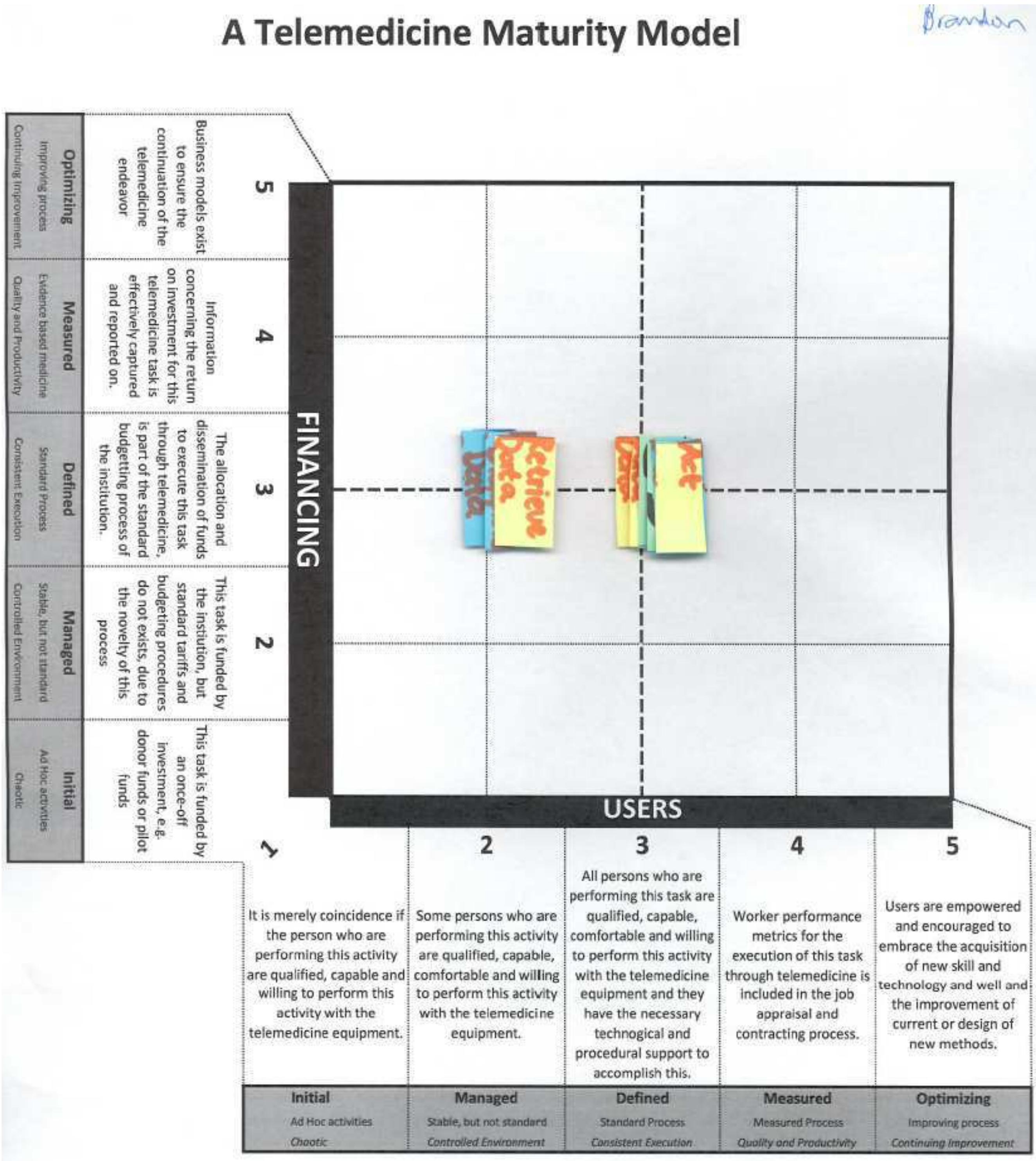
Individual / attempt Ad Hoc / Uncontrolled
Standard practice Stable
Integrated / Monitored / Strategic
Technology / Maintenance
Policy
Individual / Acceptance / Learning / Internal
Organizational / Protocols / Workflow / Management / Work Practices / Reimbursem
Planning / Budgetting / Business Model (Medium term)
Society / External / Institutions / Vendors
e-Readiness Categories


A Telemedicine Maturity Model
Brandon
FINANCING
5
Business models exist to ensure the continuation of the telemedicine endeavor
Optimizing
Improving process
Continuing Improvement
4
Information concerning the return on investment for this telemedicine task is effectively captured and reported on.
Measured
Evidence based medicine
Quality and Productivity
3
The allocation and dissemination of funds to execute this task through telemedicine, is part of the standard budgeting process of the institution.
Defined
Standard Process
Consistent Execution
2
This task is funded by the institution, but standard tariffs and budgeting procedures do not exists, due to the novelty of this process
Managed
Stable, but not standard
Controlled Environment
1
This task is funded by an once-off investment, e.g. donor funds or pilot funds
Initial
Ad Hoc activities
Chaotic
Retrieve Data
Data
Act
USERS
1
It is merely coincidence if the person who are performing this activity are qualified, capable and willing to perform this activity with the telemedicine equipment.
2
Some persons who are performing this activity are qualified, capable, comfortable and willing to perform this activity with the telemedicine equipment.
3
All persons who are performing this task are qualified, capable, comfortable and willing to perform this activity with the telemedicine equipment and they have the necessary technological and procedural support to accomplish this.
4
Worker performance metrics for the execution of this task through telemedicine is included in the job appraisal and contracting process.
5
Users are empowered and encouraged to embrace the acquisition of new skill and technology and well and the improvement of current or design of new methods.
Initial
Ad Hoc activities
Chaotic
Managed
Stable, but not standard
Controlled Environment
Defined
Standard Process
Consistent Execution
Measured
Measured Process
Quality and Productivity
Optimizing
Improving process
Continuing Improvement

Appendix F

Capability Statement Sheets

F.1 Capability Statements per Type of Service

Capability statements per type of service (capture, diagnose, transmit, meso, macro) presented along the maturity scale and domain dimension: Capture processes (Figure F.1), transmit processes (Figure F.2), mesolevel processes (Figure F.3) and macrolevel processes (Figure F.4).

F.2 Capability Statements per Maturity Level

The statements are presented along the domain and service dimensions per maturity level: Maturity level 1 (Figure F.5), maturity Leve1 2 (Figure F.6), maturity level 3 (Figure F.7), maturity level 4 (Figure F.8) and maturity level 5 (FigureF.9).

F.3 Guidelines for Further Actions

The guidelines presented in figures F.10 and F.11 are derived from the capability statements of the TMSMM. Once an assessment of a service is completed, these guidelines can be consulted. The computerized tool that was developed for purposes of this study used these guideline sheets to automatically derive as report:

	Man	Machine	Material	Method	Money
	patient or healthcare worker	telemedicine device/ mobile phone/ app etc.	data	work procedure	operational costs
no	is not available.	never existed.	do not exist.	does not exist.	are not funded.
Level 1	is available, but not always at the appropriate time.	is confirmed to be safe.	are of varying and most often unacceptable quality.	is executed on a trial and error basis.	are not considered by developers/ entrepeneur.
	is normally available a the appropriate time	is used on an ad hoc/ experimental basis.	are of varying but most often acceptable quality.	differs from person to person and case to case.	are considered and covered by seed funds while service is in development.
Level 2	wants to execute this process.	is effective and available, but still undergoes frequent modifications.	are created consistently at a mostly acceptable quality.	is executed repeatably.	will be covered on short term by seed funds.
	executes this process consistently.	is effective, reliable and available.	are created consistently, always at an acceptable quality.	is at least as effective as the traditional healthcare service.	will be covered on long term by seed funds.
Level 3	is trained to exectue this telemedicine process as standard procedure.	is interoperating with upstream and downstream devices and applications.	's physical quality standards are defined within context of this service.	is defined and documented as standard.	are included partially as a standard budget item.
	has the mandate to execute the telemedicine process as standard procedure.	is operating according to a defined standard.	's clinical effectiveness are defined.	is aligned with ethical and legal guidelines.	are included fully as a standard budget item.
Level 4	is measured when and how he does this.	's availability is monitored.	's physical quality are measured.	: Relevant and realistic efficiency measures (outputs and inputs) are defined.	are a reporting item of the accounting system.
	is monitored and appraised when and how he does this.	'availability, reliability and maintainability are monitored.	's physical quality effectiveness measures are effectively reported.	: Efficiency measures are continuously collected and communicated to relevant decision makers	' reports are routinely scrutinized to ensure optimal use of funds.
Level 5	performance is continously improved through the execution of this service.	's corrective maintenance is executed effectively and timely.	: Causes of unacceptable quality are continuously identified.	is proven to be more efficient than the traditional healthcare service.	: Non-value-adding activities are continuously identified.
	contributes to the training and development of peers towards doing this.	's preventative maintenance and upgrades are executed effectively and timely.	: Causes of unacceptable quality are continuously and effectively addressed.	's effectiveness is continously improved.	: Non-value-adding activities are continuously eliminated.

Figure F.1: Capability statement sheet for the *capture, diagnose, react* processes

	Man	Machine	Material	Method	Money
	patient or healthcare worker	internet service, mobile phone network etc.	data/ images/ video ect.	network service	cost of transmission service
no	is not available.	never existed.	do not exist.	is not available yet/ anymore.	are not funded.
Level 1	is available, but not always at the appropriate time.	is not available anymore.	sometimes get lost.	is sometimes available. Not a specific service provider.	are not considered by developers/ entrepeneur.
	is normally available a the appropriate time	is confirmed to be available.	do not get lost.	is mostly available. Not a specific service provider.	are considered and covered by seed funds whilst service is in development phase.
Level 2	wants to execute this process.	transmits data effectively.	can easily be viewed by an unauthorized person.	is delivered by a specific (set of) service provider(s) with varying service levels.	will be covered on short term by seed funds.
	executes this process consistently.	transmits data effectively at an acceptable speed.	cannot easilty be viewed by an unauthorized person.	is delivered by a specific (set of) service provider(s) with consistent service levels.	will be covered on long term by seed funds.
Level 3	is trained to exectue this telemedicine process as standard procedure.	capacity (bandwidth) was considered in the design of the service.	are transmitted according to a standard transmissions protocol.	-level-agreements (SLAs) are defined.	are included partially as a standard budget item.
	has the mandate to execute the telemedicine process as standard procedure.	's interoperability is considered in the system's standards design.	are appropriately encrypted and decrypted.	level-agreements (SLAs) are contractually agreed upon.	are included fully as a standard budget item.
Level 4	is measured when and how he does this.	's reliability and availability can be measured.	can be tracked throughout the telemedicine service.	levels are measured.	are a reporting item of the accounting system.
	is monitored and appraised when and how he does this.	's reliability and availability are monitored.	and the identities of persons who viewed and edited them, can be tracked.	levels are continuously monitored and penalties applied.	's reports are routinely scrutinized to ensure optimal use of funds.
Level 5	performance is continously improved through the execution of this service.	: Deviations from acceptable levels of availability and reliability is continuously addressed.	: Causes of delays and incorrectly transmitted data are identified.	levels are continuously maintained.	: Continuous efforts by service provider to bring down costs.
	contributes to the training and development of peers towards doing this.	's capability, reliability and availability are continuously improved.	: Causes of delays and incorrectly transmitted EHRs are continuously addressed.	levels are continuously improved.	: Continuous efforts by service provider to bring down costs are filtered through to service context.

Figure F.2: Capability statement sheet for the *transmit* processes

	Man	Machine	Material	Method	Money
	healthcare worker community	physical infrastructure	electronic medical records (EMRs)	change management process	interorganizational business model
no	is not aware of this service.	never existed.	do not exist.	does not exist.	is not available yet/anymore
Level 1	resists this service.	is neither appropriate nor available.	do not exist / exist only in paper format.	has not been considered.	has never been considered for the interorganization that spans the telemedicine service.
	avoids this service.	is either not appropriate or not available.	are kept and stored by user while telemedicine process is in progress.	was ineffective. The process regressed back to old method after the pilot phase.	has been considered for the interorganization that spans the telemedicine service.
Level 2	's perception is that this service is easy to use.	is appropriate and mostly available.	are kept on telemedicine device.	is executed by an entrepreneur.	has been considered for the interorganization that spans the telemedicine service.
	's perception is that this service will contribute to job performance.	is appropriate and always available.	are kept on a local databasis specific to telemedicine service.	is driven by an (at least) self-appointed champion.	includes all stakeholders.
Level 3	considers this service as mandatory.	is set up specifically for this service and is always available.	are linked with hospital information system (HIS).	is driven by someone that is formally and permanently appointed for this purpose.	: the way in which value is created is clear and sustainable.
	's organizational culture strengthens the use of this service.	is set up specifically for this service according to defined design standards.	are integrated with hospital information system (HIS).	is integrated with other business processes (e.g. budget, facilities planning, service redesign).	will sustain without donor funds/ seed funds.
Level 4	's adoption of the service is measured.	's availability is monitored.	are managed in such a way that the can be transformed into management information.	is linked to key performance indicators (KPIs).	:Costs and benefits are realistically measured.
	's adoption of the service are measured by means of scientifically evidence-based study.	'availability, reliability and maintainability are monitored.	are routinely transformed into management information and considered by relevant decision makers.	is monitored in terms of these KPIs.	: Cost-benefit analyses are continuously performed.
Level 5	: The service contributes to the professional development and positive task shift of the users.	is scalable (can easily be expanded to accommodate more instances of this service).	: Ad hoc management decisions related to telemedicine services are based on this information.	addresses deviations from key performance targets.	: How the organization creates, delivers and captures value are continuously improved.
	continuous improvement	is continuously maintained and upgraded whenever needed.	: Continuous management decisions related to telemedicine services are based on this information.	continuously improves on key performance targets.	is successfully replicated elsewhere.

Figure F.3: Capability statement sheet for the *meso*level processes

	Man	Machine	Material	Method	Money
	society	interorganizational system	electronic health records (EHRs)	policies and strategies	national business case
no	is not aware of this service.	never included the telemedicine service.	do not exist.	related to the telemedicine service are not known.	is not available yet/anymore
Level 1	may be aware, but is not deliberately made aware of this service.	can not accommodate the telemedicine service.	do not exist / exist only in paper format.	are ignored at this stage.	has never been considered
	is deliberately made aware of this service.	's technology and resources are not synchronized.	of telemedicine service are not kept on record after completion of the service.	are in conflict with the telemedicine services.	has never been considered
Level 2	is willing to receive this service.	's technology and resources are sometimes synchronized.	are linked to an existing EHR management system.	: the service are adapted to fit the strategies.	:pockets of organized value creationg
	wants to receive this service.	's technology and resources are mostly synchronized.	of telemedicine service are available centrally to all facilities that took part in process.	: the service are adapted to fit the policies and strategies.	:nationally organized value creation.
Level 3	:(a sufficiently large portion of) already used this service for most issues to be addressed.	's interoperability standards are defined.	are integrated with an existing EHR management system.	are aligned with the processes of the telemedicine service.	: national funding structures are in place.
	considers this telemedicine service as the norm.	's interoperability standards are followed throughout the system.	are integrated with an existing EHR management system.	: strategies are adapted to fit the telemedicine services.	: processes for the reimbursement of telemedicine services are in place.
Level 4	: the impact on the society is known and monitored.	: KPIs are defined with the new organizational design in mind.	are managed in such a way that they can be transformed into management information.	are linked to health indicators.	: The health-economic impact of the service are measured.
	: the impact on the society is scientifically quantified.	: KPIs are routinely measured and reported on.	are routinely transformed into management information and considered by relevant decision-makers.	facilitate the systematic evaluation of this telemedicine service.	Health economics metrics are used as decision input to health systems strengthening.
Level 5	: The service is continuously improved and scaled up to increase benefit to the society.	is continuously adopted to fit the need.	: Ad hoc management decisions related to telemedicine services are based on this information.	facilitate the sharing of best practices and management of knowledge of this service.	: The service has a significant socio-economic impact on the nation.
	: Other similar societies can learn from the example of this service.	is scalable (can easily be expanded to accommodate more instances of this service).	: Continuous management decisions related to telemedicine services are based on this information.	continuously facilitate the dissemination of best practices.	: The impact of the service on the socio-economic well-being of the nation is continously expanded.

Figure F.4: Capability statement sheet for the *macro* processes

		Capture, Diagnose/ Analyze, React	Data Transmission processes		Meso-level processes	Macro-level processes
Man	entrepreneur	The patient or healthcare worker is available, but not always at the appropriate time.	The patient or healthcare worker is available, but not always at the appropriate time.	resistance / ignorance	The healthcare worker community resists this service.	The society may be aware, but is not deliberately made aware of this service.
		The patient or healthcare worker is normally available a the appropriate time	The patient or healthcare worker is normally available a the appropriate time		The healthcare worker community avoids this service.	The society is deliberately made aware of this service.
Machine	experiment	The physical infrastructure is neither appropriate nor available.	The internet service, mobile phone network etc. is not available anymore.	insufficient	The physical infrastructure is neither appropriate nor available.	The interorganizational system can not accommodate the telemedicine service.
		The telemedicine device/ mobile phone/ app etc. is used on an ad hoc/ experimental basis.	The internet service, mobile phone network etc. is confirmed to be available.		The physical infrastructure is either not appropriate or not available.	The interorganizational system 's technology and resources are not synchronized.
Material	uncertain quality	The dataare of varying and most often unacceptable quality.	The data/ images/ video ect.sometimes get lost.	temporary	The electronic medical records (EMRs)do not exist / exist only in paper format.	The electronic health records (EHRs) do not exist / exist only in paper format.
		The data are of varying but most often acceptable quality.	The data/ images/ video ect.do not get lost.		The electronic medical records (EMRs)are kept and stored by user while telemedicine process is in progress.	The electronic health records (EHRs) of telemedicine service are not kept on record after completion of the service.
Method	ad hoc	The work procedure is executed on a trial and error basis.	The network service is sometimes available. Not a specific service provider.	experiment	The change management process has not been considered.	The policies and strategies are ignored at this stage.
		The work procedure differs from person to person and case to case.	The network service is mostly available. Not a specific service provider.		The change management process was ineffective. The process regressed back to old method after the pilot phase.	The policies and strategies are in conflict with the telemedicine services.
Money	R and D / entre-peneur	The operational costs are not considered by developers/ entrepeneur.	The cost of transmission service are not considered by developers/ entrepeneur.	fragmented	The interorganizational business model has never been considered	The national business case has never been considered
		The operational costs are considered and covered by seed funds while service is in development.	The cost of transmission service are considered and covered by seed funds whilst service is in development phase.		The interorganizational business model has never been considered for the interorganization that spans the telemedicine service.	The national business case has never been considered

Figure F.5: Capability statement sheet for *maturity level 1*

		Capture, Diagnose/ Analyze, React	Data Transmission processes		Meso-level processes	Macro-level processes
Man	champion	The patient or healthcare worker wants to execute this process.	The patient or healthcare worker wants to execute this process.	acceptance	The healthcare worker community 's perception is that this service is easy to use.	The society is willing to receive this service.
		The patient or healthcare worker executes this process consistently.	The patient or healthcare worker executes this process consistently.		The healthcare worker community 's perception is that this service will contribute to job performance.	The society wants to receive this service.
Machine	pilot	The telemedicine device/ mobile phone/ app etc. is effective and available, but still undergoes frequent modifications.	The internet service, mobile phone network etc. transmits data effectively.	managed	The physical infrastructure is appropriate and mostly available.	The interorganizational system 's technology and resources are sometimes synchronized.
		The telemedicine device/ mobile phone/ app etc. is effective, reliable and available.	The internet service, mobile phone network etc. transmits data effectively at an acceptable speed.		The internet service, mobile phone network etc. is appropriate and always available.	The 's technology and resources are mostly synchronized.
Material	consistent quality	The data are created consistently at a mostly acceptable quality.	The data/ images/ video ect.can easily be viewed by an unauthorized person.	isolated	The electronic medical records (EMRs)are kept on telemedicine device.	The electronic health records (EHRs) of telemedicine service are available to all facilities that took part in process, but not centrally. Duplicates of the record are kept by respective
		The dataare created consistently, always at an acceptable quality.	The data/ images/ video ect.cannot easilty be viewed by an unauthorized person.		The electronic medical records (EMRs)are kept on a local databasis specific to telemedicine service.	The electronic health records (EHRs) of telemedicine service are available centrally to all facilities that took part in process.
Method	effective	The work procedure is executed repeatably.	The network service is delivered by a specific (set of) service provider(s) with varying service levels.	bottom-up	The change management process is executed by an entrepreneur.	The policies and strategies : the service are adapted to fit the strategies.
		The work procedure is at least as effective as the traditional healthcare service.	The network service is delivered by a specific (set of) service provider(s) with consistent service levels.		The change management process is driven by an (at least) self-appointed champion.	The policies and strategies : the service are adapted to fit the policies and strategies.
Money	consistent, but temporary	The operational costs will be covered on short term by seed funds.	The cost of transmission service will be covered on short term by seed funds.	synergy	The interorganizational business model has been considered for the interorganization that spans the telemedicine service.	The national business case :pockets of organized value creationg
		The operational costs will be covered on long term by seed funds.	The cost of transmission service will be covered on long term by seed funds.		The interorganizational business model includes all stakeholders.	The national business case :nationally organized value creation.

Figure F.6: Capability statement sheet for *maturity level 2*

		Capture, Diagnose/ Analyze, React	Data Transmission processes		Meso-level processes	Macro-level processes
Man	standard	The patient or healthcare worker is trained to exectue this telemedicine process as standard procedure.	The patient or healthcare worker is trained to exectue this telemedicine process as standard procedure.	norm	The healthcare worker community considers this service as mandatory.	The society :(a sufficiently large portion of) already used this service for most issues to be addressed.
		The patient or healthcare worker has the mandate to execute the telemedicine process as standard procedure.	The patient or healthcare worker has the mandate to execute the telemedicine process as standard procedure.		The healthcare worker community 's organizational culture strengthens the use of this service.	The society considers this telemedicine service as the norm.
Machine	standards and inter-operability	The telemedicine device/ mobile phone/ app etc. is interoperating with upstream and downstream devices and applications.	The internet service, mobile phone network etc. capacity (bandwidth) was considered in the design of the service.	standards and inter-operability	The physical infrastructure is set up specifically for this service and is always available.	The interorganizational system 's interoperability standards are defined.
		The telemedicine device/ mobile phone/ app etc. is operating according to a defined standard.	The internet service, mobile phone network etc. 's interoperability is considered in the system's standards design.		The physical infrastructure is set up specifically for this service according to defined design standards.	The interorganizational system 's interoperability standards are followed throughout the system.
Material	quality standards	The data's physical quality standards are defined within context of this service.	The data/ images/ video ect.are transmitted according to a standard transmissions protocol.	integrated	The electronic medical records (EMRs)are linked with hospital information system (HIS).	The electronic health records (EHRs) are linked to an existing EHR management system.
		The data's clinical effectiveness are defined.	The data/ images/ video ect.are appropriately encrypted and decrypted.		The electronic medical records (EMRs)are integrated with hospital information system (HIS).	The electronic health records (EHRs) are integrated with an existing EHR management system.
Method	work standards	The work procedure is defined and documented as standard.	The network service -level-agreements (SLAs) are defined.	top-down	The change management process is driven by someone that is formally and permanently appointed for this purpose.	The policies and strategies : strategies are adapted to fit the telemedicine services.
		The work procedure is aligned with ethical and legal guidelines.	The network service level-agreements (SLAs) are contractually agreed upon.		The change management process is integrated with other business processes (e.g. budget, facilities planning, service redesign).	The policies and strategies are aligned with the processes of the telemedicine service.
Money	consistent and permanent	The operational costs are included partially as a standard budget item.	The cost of transmission service are included partially as a standard budget item.	sustainable	The interorganizational business model : the way in which value is created is clear and sustainable.	The national business case : national funding structures are in place.
		The operational costs are included fully as a standard budget item.	The cost of transmission service are included fully as a standard budget item.		The interorganizational business model will sustain without donor funds/ seed funds.	The national business case : processes for the reimbursement of telemedicine services are in place.

Figure F.7: Capability statement sheet for *maturity level 3*

		Capture, Diagnose/ Analyze, React	Data Transmission processes		Meso-level processes	Macro-level processes
Man	performance management	The patient or healthcare worker is measured when and how he does this.	The patient or healthcare worker is measured when and how he does this.	evidence	The healthcare worker community 's adoption of the service is measured.	The society : the impact on the society is known and monitored.
		The patient or healthcare worker is monitored and appraised when and how he does this.	The patient or healthcare worker is monitored and appraised when and how he does this.		The healthcare worker community 's adoption of the service are measured by means of scientifically evidence-based study.	The society : the impact on the society is scientifically quantified.
Machine	monitored	The telemedicine device/ mobile phone/ app etc. 's availability is monitored.	The internet service, mobile phone network etc. 's reliability and availability can be measured.	monitored	The physical infrastructure 's availability is monitored.	The interorganizational system : KPIs are defined with the new organizational design in mind.
		The telemedicine device/ mobile phone/ app etc. 'availability, reliability and maintainability are monitored.	The internet service, mobile phone network etc. 's reliability and availability are monitored.		The physical infrastructure 'availability, reliability and maintainability are monitored.	The interorganizational system : KPIs are routinely measured and reported on.
Material	quality control	The data's physical quality are measured.	The data/ images/ video ect.can be tracked throughout the telemedicine service.	business intelligence	The electronic medical records (EMRs)are managed in such a way that the can be transformed into management information.	The electronic health records (EHRs) are managed in such a way that they can be transformed into management information.
		The data 's physical quality effectiveness measures are effectively reported.	The data/ images/ video ect.and the identities of persons who viewed and edited them, can be tracked.		The electronic medical records (EMRs)are routinely transformed into management information and considered by relevant decision makers.	The electronic health records (EHRs) are routinely transformed into management information and considered by relevant decision-makers.
Method	performance control	The work procedure : Relevant and realistic efficiency measures (outputs and inputs) are defined.	The network service levels are measured.	performance and health indicators	The change management process is linked to key performance indicators (KPIs).	The policies and strategies are linked to health indicators.
		The work procedure : Efficiency measures are continuously collected and communicated to relevant decision makers.	The network service levels are continuously monitored and penalties applied.		The change management process is monitored in terms of these KPIs.	The policies and strategies facilitate the systematic evaluation of this telemedicine service.
Money	accountability	The operational costs are a reporting item of the accounting system.	The cost of transmission service are a reporting item of the accounting system.	health economics	The interorganizational business model :Costs and benefits are realistically measured.	The national business case : The health-economic impact of the service are measured.
		The operational costs ' reports are routinely scrutinized to ensure optimal use of funds.	The cost of transmission service 's reports are routinely scrutinized to ensure optimal use of funds.		The interorganizational business model : Cost-benefit analyses are continuously performed.	The national business case Health economics metrics are used as decision input to health systems strengthening.

Figure F.8: Capability statement sheet for *maturity level 4*

		Capture, Diagnose/ Analyze, React	Data Transmission processes		Meso-level processes	Macro-level processes
Man	professional development	The patient or healthcare worker performance is continously improved through the execution of this service.	The patient or healthcare worker performance is continously improved through the execution of this service.	change to community	The healthcare worker community : The service contributes to the professional development and positive task shift of the users.	The society : The service is continuously improved and scaled up to increase benefit to the society.
		The patient or healthcare worker contributes to the training and development of peers towards doing this.	The patient or healthcare worker contributes to the training and development of peers towards doing this.		The healthcare worker community : Continuous capacity building of the healthcare worker community.	The society : Other similar societies can learn from the example of this service.
Machine	maintenance and upgrades	The telemedicine device/ mobile phone/ app etc. 's corrective maintenance is executed effectively and timely.	The internet service, mobile phone network etc. : Deviations from acceptable levels of availability and reliability is continuously addressed.	continuous improvement	The physical infrastructure is continuously maintained and upgraded whenever needed.	The interorganizational system is continuously adopted to fit the need.
		The telemedicine device/ mobile phone/ app etc. 's preventative maintenance and upgrades are executed effectively and timely.	The internet service, mobile phone network etc. 's capability, reliability and availability are continuously improved.		The physical infrastructure is scalable (can easily be expanded to accommodate more instances of this service).	The interorganizational system is scalable (can easily be expanded to accommodate more instances of this service).
Material	quality improvement	The data: Causes of unacceptable quality are continuously identified.	The data/ images/ video ect.: Causes of delays and incorrectly transmitted data are identified.	business optimization	The electronic medical records (EMRs): Ad hoc management decisions related to telemedicine services are based on this information.	The electronic health records (EHRs) : Ad hoc management decisions related to telemedicine services are based on this information.
		The data: Causes of unacceptable quality are continuously and effectively addressed.	The data/ images/ video ect.: Causes of delays and incorrectly transmitted EHRs are continuously addressed.		The electronic medical records (EMRs): Continuous management decisions related to telemedicine services are based on this information.	The electronic health records (EHRs) : Continuous management decisions related to telemedicine services are based on this information.
Method	continuous improvement	The work procedure is proven to be more efficient than the traditional healthcare service.	The network service levels are continuously maintained.	continuous improvement	The change management process addresses deviations from key performance targets.	The policies and strategies facilitate the sharing of best practices and management of knowledge of this service.
		The work procedure 's effectiveness is continosuly improved.	The network service levels are continuously improved.		The change management process continuously improves on key performance targets.	The policies and strategies continuously facilitate the dissemination of best practices.
Money	cost optimization	The operational costs : Non-value-adding activities are continuously identified.	The cost of transmission service : Continuous efforts by service provider to bring down costs.	value optimization	The interorganizational business model : How the organization creates, delivers and captures value are continuously improved.	The national business case : The service has a significant socio-economic impact on the nation.
		The operational costs : Non-value-adding activities are continuously eliminated.	The cost of transmission service : Continuous efforts by service provider to bring down costs are filtered through to service context.		The interorganizational business model is successfully replicated elsewhere.	The national business case : The impact of the service on the socio-economic well-being of the nation is continously expanded.

Figure F.9: Capability statement sheet for *maturity level 5*

Capture / Diagnose / React	Man		Machine		Material		Method		Money
	patient/ doctor/ nurse etc.	use (s)	telemedicine device/ mobile phone ect.	to …	EHR data/ images/ video ect.	acco r-	work procedure	at the	operational costs
Current Maturity Level	Actions to consider	Current Maturity	Actions to consider	Current Maturity	Actions to consider	Current Maturity	Actions to consider	Current Maturity	Actions to consider
1a entre-perneur	Put measures in place to motivate user to execute this process.	experiment	Continue with development to accomplish effectiveness and availability.	uncertain quality	Adjust process and technology until quality of records are repeated.	ad hoc	Develop a repeatable procedure for this service.	R and D / entrepeneur	Secure development funds for next phase.
1b entre-perneur	Put measures in place to motivate user to execute this process consistently.	experiment and pilot	Continue with development to accomplish effectiveness, availability and reliability.	uncertaing/cons itent quality	Adjust process and technology until quality of records are repeated.	ad hoc	Develop a repeatable procedure, which is at least as effective as the traditional procedure.	consitent, but temporary	Secure medium-term development funds.
2a champion	Communicate to users that the telemedicine service is the standard in this context.	prototype/ pilot	Determine stardard technology for purposes of this service.	consistent quality	Define quality standards for electronic record.	effective	Conduct a method study on existing process to develop a standard process.	consistent, but temporary	Include operational costs in the standard budget process.
2b champion	Manage this telemedicine service as standard.	prototype/ pilot	Ensure interoperability between other devices and applications.	consistent quality	Define quality standards for electronic record.	effective	Ensure that the method adheres to ethical and legal guidelines.	consistent, but temporary	Include operational costs in the standard budget process.
3a standard	Determine appropriate and measurable metrics.	standards and inter-operability	Measure and monitor effectiveness and availability	quality standards	Determine appropriate and measurable quality metrics.	work standards	Identify measurable process inputs and outputs.	consistent and permanent	Develop a cost-benefit measure for this telemedicine service.
3b standard	Continuously administer these metrics and compile timely reports.	standards and inter-operability	Measure and monitor effective, availability and reliability.	quality standards	Continuously administer these metrics and compile timely reports.	work standards	Include processes in the work procedure so that these inputs and outputs are continuously measured.	consistent and permanent	Include these telemedicine cost-benefit measures in the termly reports.
4a performance ma	Support the user in improving the way in which he executes the service.	monitored	Execute corrective maintenance effectively and timely.	quality control	Continuously identify causes for unacceptable quality.	performance control	Continuously idendify and addressed reasons for inefficiencies.	account-ability	Apply lean healthcare principles to continuously identify non-value adding activities.
4b performance ma	contributes to the training and development of peers towards doing this.	monitored	Execute preventative maintenance and upgrades effectively and timely.	quality control	Continuously identify causes for unacceptable quality.	performance control	Encourage and facilitate continuous efficiency improvement.	account-ability	Apply lean healthcare principles to continuously eliminate non-value adding activities.
5a professional	Maintain target maturity state.	maintenance and upgrades	Maintain target maturity state.	quality improvement	Maintain target maturity state.	continuous improvement	Maintain target maturity state.	cost optimization	Maintain target maturity state.
5b professional	Maintain target maturity state.	maintenance and upgrades	Maintain target maturity state.	quality improvement	Maintain target maturity state.	continuous improvement	Maintain target maturity state.	cost optimization	Maintain target maturity state.

Figure F.10: Guidelines for further actions: diagnose, analyse and react processes

Transmit									
	Man	Machine		Material		Method		Money	
	patient/ doctor/ nurse etc.	use (s)	dimension data network	to …	EHR data/ images/ video ect.	acco r-	dimension data service	at the	local clinic.
Current Maturity Level	Actions to consider	Current Maturity	Actions to consider	Current Maturity	Actions to consider	Current Maturity	Actions to consider	Current Maturity	Actions to consider
1 entrepreneur	Put measures in place to motivate user to execute this process.	experiment	Test availability of data transmission.	uncertain quality	Define a transmissions protocol.	ad hoc	Indentify available service providers.	R and D / entre-peneur	Ringfence funds to data transmission.
entrepreneur	Put measures in place to motivate user to execute this process consistently.	experiment and pilot	Test effectiveness of data transmission.	uncertaing/consitent quality	Define a transmissions protocol.	ad hoc	Engage with service providers.	consitent, but temporary	Ringfence funds to data transmission.
2 champion	Communicate to users that the telemedicine service is the standard in this context.	prototype/ pilot	Determine peak bandwidth. Test effectiveness of data transmission under these circumstances.	consistent quality	Define a transmissions protocol.	effective	Negotiate dedicated service with (a) service provider(s).	consistent, but temporary	Include data transmission funds as standard budget item.
champion	Manage this telemedicine service as standard.	prototype/ pilot	Consider interface specifications of all devices in this service.	consistent quality	Consider encryption and decription protocol.	effective	Define service level agreements.	consistent, but temporary	Include data transmission funds as standard budget item.
3 standard	Determine appropriate and measurable metrics.	standards and inter-operability	Define measures for realiability and availability.	quality standards	Put measures in place to track progress of telemedicine service.	work standards	Development measures to monitor adherance to service level agreements.	consistent and perma-nent	Include transmission costs in accounting reports.
standard	Continuously administer these metrics and compile timely reports.	standards and inter-operability	Put processes in place to continuously measure realibility and availability	quality standards	Link identities of users to tracking of telemedicine service.	work standards	Development measures to monitor adherance to service level agreements (SLAs).	consistent and perma-nent	Include transmission costs in accounting reports.
4 performance ma	Support the user in improving the way in which he executes the service.	monitored	Put processes in place to ensure timely upgrades and licence renewal.	quality control	can be tracked throughout the telemedicine service.	perfor-mance control	Ensure that service level agreements are maintained.	account-ability	Continuously scrutinize transmission costs.
performance ma	contributes to the training and development of peers towards doing this.	monitored	Pro-actively maintain devices.	quality control	and identities of persons who viewed and edited it, can be tracked.	perfor-mance control	Ensure that service level agreements are maintained.	account-ability	Continuously scrutinize transmission costs.
professional devi	Maintain target maturity state.	maintenance and upgrades	Maintain target maturity state.	quality improve-ment	Maintain target maturity state.	continuous improve-ment	Maintain target maturity state.	cost opti-mization	Maintain target maturity state.
5 professional dev	Maintain target maturity state.	maintenance and upgrades	Maintain target maturity state.	quality improve-ment	Maintain target maturity state.	continuous improve-ment	Maintain target maturity state.	cost opti-mization	Maintain target maturity state.

Figure F.11: Guidelines for further actions: transmit data process

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