A systems engineering approach: The application of lean thinking to support sustainability transitions in healthcare

By

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering (Engineering Management) in the Faculty of Engineering at Stellenbosch University

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March 2023

DECLARATION

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ABSTRACT

Sustainable healthcare systems have become increasingly difficult to achieve because of the large amount of competition in the healthcare industry. The healthcare industry needs to move away from the current situation to deliver higher quality, full-access, affordable, and sustainable healthcare services. The status quo of sustainability transitions in healthcare is currently lacking in drivers which support the socio-technical transition to increased sustainable states. Sustainability in healthcare is a relatively novel concept, but it contributes to solving some of the increasing challenges faced in the healthcare industry. By increasing the economic-, social-, and environmental sustainability in healthcare systems, a significant amount of waste can be eliminated while achieving the sustainable development goals set out by the United Nations to be met by 2030. Lean implementations in healthcare systems have proven difficult because the improvements are not maintained, and the system tends to return to its previous unsustainable and non-lean system state. Thus, healthcare systems, as socio-technical systems, are deemed unsustainable. Socio-technical transitions in healthcare systems have increasingly been analysed to understand how they can be designed to increase sustainability and thus assist in achieving sustainable development goals. Given this global sustainability challenge in healthcare systems, it is deemed necessary to develop methods and approaches to ease the transition process to more sustainable system states. Lean thinking and sustainability are interconnected regarding their objectives and aims in system processes. Therefore, incorporating lean thinking into sustainability transitions can strengthen the value creation of system processes by efficiently allocating and consuming resources while ensuring waste elimination during system processes.

Thus, this research aims to use lean thinking to support the progression of sustainability transitions in relation to healthcare systems. Literature has proven that lean implementation is a strong driver for increased sustainability. Thus, implementing lean thinking into sustainability transitions strengthens the sustainability transition. This is achieved by developing the lean thinking for sustainability transitions in healthcare (LT4STHC) framework, which uses the author's developed methodology and LT4ST index to determine which lean thinking approaches or principles could be used to address specific aspects of sustainability transitions in relation to healthcare systems. These aspects include but are not limited to landscape tensions, regime stresses, niche pressures, transition weaknesses, and transition failures.

The developed framework, methodology, and index were evaluated in three ways. The framework, methodology, and index were assessed against the requirement specifications for its development. The self-assessment demonstrated that the framework, methodology, and index met the stipulated requirement specifications for its development. Interviews were conducted with subject matter experts (SMEs) in lean, healthcare, or sustainability and sustainability transitions. SMEs verified the theoretical accuracy and tenability of the framework, methodology, and index content. The SMEs were requested to complete questionnaires. A further evaluation of the developed framework, methodology, and index was conducted through a practical application in the form of a case study. Finally, the case study application of the framework, methodology, and index demonstrated its applicability, practicability, and usability.

The LT4STHC framework, methodology, and LT4ST index achieved the intended goal of implementing lean thinking approaches and principles into sustainability transitions to support its progression towards an even greater sustainable state. The overall evaluation of the framework, methodology, and index demonstrates that the developed research products achieve the stated

research aim and provide assertion to using lean thinking to support sustainability transitions in healthcare.

OPSOMMING

Volhoubare gesondheidsorgstelsels het al hoe moeiliker geword om te bereik as gevolg van die groot hoeveelheid mededinging in die gesondheidsorgbedryf. Die gesondheidsorgbedryf moet wegbeweeg van die huidige stand van sake in 'n poging om hoër gehalte, volle toegang, bekostigbare en volhoubare gesondheidsorgdienste te lewer. Die status quo van volhoubaarheidsoorgange in gesondheidsorg ontbreek tans aan drywers wat die sosio-tegniese oorgang na verhoogde volhoubare state ondersteun. Volhoubaarheid in gesondheidsorg is 'n redelik nuwe konsep, maar dit dra by tot die oplossing van sommige van die toenemende uitdagings wat die gesondheidsorgbedryf in die gesig staar. Deur die ekonomiese, sosiale en omgewingsvolhoubaarheid in gesondheidsorgstelsels te verhoog, kan 'n aansienlike hoeveelheid vermorsing uitgeskakel word terwyl die "sustainable development goals" wat deur die Verenigde Nasies uiteengesit is, bereik word teen 2030. Lean implementerings in gesondheidsorgstelsels het geblyk 'n moeilike taak te wees omdat die verbeterings nie in stand gehou word nie en die stelsel is geneig om terug te keer na sy vorige, onvolhoubare en "non-lean", stelseltoestand. Gesondheidsorgstelsels, as sosio-tegniese stelsels, word dus as onvolhoubaar beskou. Sosio-tegniese oorgange in gesondheidsorgstelsels is toenemend ontleed om te verstaan hoe dit ontwerp kan word om volhoubaarheid te verhoog en sodoende te help met die bereiking van "sustainable development goals". Gegewe hierdie globale volhoubaarheidsuitdaging in gesondheidsorgstelsels, word dit nodig geag om metodes en benaderings te ontwikkel wat help om die oorgangsproses na meer volhoubare stelselstate te vergemaklik. "Lean thinking" en volhoubaarheid is met mekaar verbind in terme van hul doelwitte en oogmerke in sisteemprosesse. Die inkorporering van "lean thinking" in volhoubaarheidsoorgange kan dus die waardeskepping van stelselprosesse versterk deur hulpbronne doeltreffend toe te ken en te verbruik, terwyl dit verseker dat afval tydens stelselprosesse verwyder word.

Die doel van hierdie navorsing is dus om "lean thinking" te gebruik om die vordering van volhoubaarheidsoorgange in gesondheidsorgstelsels te ondersteun. Literatuur het bewys dat "lean thinking" ‘n sterk dryfveer vir verhoogde volhoubaarheid is, dus die implementering van "lean thinking" in volhoubaarheidsoorgange versterk die volhoubaarheidsoorgang. Hierdie doel word bereik deur die ontwikkeling van die "lean thinking for sustainability transitions in healthcare (LT4STHC)" raamwerk, wat gebruik maak van die skrywer se ontwikkelde metodologie en indeks om te help om te bepaal watter "lean thinking" denkbenaderings of -beginsels spesifieke aspekte van volhoubaarheidsoorgange in gesondheidsorg kan toespreek. Hierdie aspekte sluit in, maar is nie beperk tot, die voorkoms van landskapspanning, regime-spanning, nisdruk, oorgangsswakhede, oorgangsmislukkings, ens.

Die ontwikkelde raamwerk, metodologie, en indeks is op drie maniere geëvalueer. Die raamwerk, metodologie en indeks is geassesseer teen die vereiste spesifikasies vir die ontwikkeling daarvan. Die selfevaluering het getoon dat die raamwerk, metodologie en indeks aan die vereiste vereiste spesifikasies vir die ontwikkeling daarvan voldoen het. Onderhoude is gevoer met vakkundiges ("SMEs") in lean, gesondheidsorg, of volhoubaarheid en volhoubaarheid oorgange. SMEs het die teoretiese akkuraatheid en houdbaarheid van die raamwerk, metodologie en indeks inhoud geverifieer. Die SMEs is versoek om vraelyste te voltooi. 'n Verdere evaluering van die ontwikkelde raamwerk, metodologie, en indeks is uitgevoer deur 'n praktiese toepassing in die vorm van 'n gevallestudie. Laastens het die gevallestudietoepassing van die raamwerk, metodologie en indeks die toepaslikheid, uitvoerbaarheid en bruikbaarheid daarvan gedemonstreer.

Die algehele evaluering van die raamwerk, metodologie, en indeks demonstreer dat die ontwikkelde navorsingsprodukte die gestelde navorsingsdoelwit bereik en die bewering verskaf om "lean thinking" te gebruik om die vordering van volhoubaarheidsoorgange in gesondheidsorg te ondersteun.

ACKNOWLEDGMENTS

My sincere gratitude is extended to my supervisor, Prof. Imke de Kock, for the privilege of doing this research with her support and under her supervision. Thank you for everything you have done during this development phase of my life.

Thank you to the Department of Industrial Engineering for my support as a student. A special thank you to the administrative staff for the encouragement and assistance they provided during the completion of my research.

I commend and thank the subject matter experts for their time and expertise in making contributions to validate this research. I greatly appreciate their feedback and have gained much insight from the conversations that were had.

To my M.Eng (Industrial Engineering) peers: Thank you for the discussions and for always listening when I wanted to share my ideas. Thank you for giving me advice when I encounter challenges.

A big thank you is extended to my family, especially my mom, my sister, and Tiaan, for being my support system during this process. Thank you for your love, support, and patience with me. Thank you for providing a shoulder I could cry on during the more challenging times.

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NOMENCLATURE

ACRONYMNS

AP	Attention points
APDN	Diagnostic analytical perspective
APDS	Descriptive analytical perspective
APPD	Predictive analytical perspective
APPS	Prescriptive analytical perspective
ASC	Ambulatory surgery centres
BC	Boundary conditions
CE	Circular economy
CSR	Corporate social responsibility
DR	Design restrictions
DRM	Disaster risk management
FR	Functional requirements
HC	Healthcare
HCRW	Healthcare risk waste
HFE	Human factors engineering
ID	Identification
INCOSE	International Council on Systems Engineering
ISA	Innovation system approach
IT	Information technology
LT4ST	Lean thinking for sustainability transitions
LT4STHC	Lean thinking for sustainability transitions in healthcare
MLP	Multi-level perspective
NGO	Non-government organisation
NIS	National innovation systems
QI	Quality improvement
RCA	Root cause analysis
RIS	Regional innovation systems

RO	Research objective
RST	Resilience of sustainability transitions
SBM	Sustainability business model
SC	Search combination
SDG	Sustainable Development Goal
SE	Systems Engineering
SME	Subject matter expert
SNM	Strategic niche management
STS	Socio-technical system
STT	Socio-technical transition
TIS	Technological innovation systems
TM	Transition management
TMO	Transition management operational level
TMR	Transition management reflexive level
TMS	Transition management strategic level
TMT	Transition management tactical level
TPS	Toyota Production System
TQM	Total quality management
UR	User requirements
VSM	Value stream mapping
WHO	World Health Organisation
WIP	Work in progress

CHAPTER 1: INTRODUCTION

This chapter provides the background of the research, thereby, the rationale for this research. The problem statement, the research objectives, the expected contribution, and the research design and strategy are discussed. Furthermore, the knowledge gap and the expected contribution are outlined. The chapter concludes with an outline of the document structure.

1.1 PROJECT BACKGROUND

Sustainability is not only a relatively new concept, but it has become more popular over time due to the increase in the need to understand and acknowledge resource scarcity. This concept originated from movements such as social justice, conservationism, and internationalism, which came together by the end of the 20th century as a collective to be called "sustainable development". In 1987 the Brundtland Commission released a famous definition for the term "sustainable development", which is the "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (University of Alberts, 2016). Sustainability is deemed a holistic approach in which economic, social, and environmental aspects must all be considered together to find a lasting existence of prosperity (University of Alberts, 2016).

Sustainable healthcare systems are the gateway to providing higher quality healthcare at lower costs while reaching large populations in a particular area and effectively managing diseases. The development of sustainable healthcare systems has increasingly become more challenging to achieve due to intense competition in the healthcare industry. Cost efficiency and the effectiveness of a healthcare system cannot be achieved simultaneously. Researchers have also proven that there is an evident compromise between the increases that occur between effectiveness and efficiency. The effectiveness is an indication of the potential of the healthcare system to be able to achieve its maximum possible output (lo Sorto & Goncharuk, 2017).

Long-term sustainability is a relevant topic considering that an increasing number of companies and organisations are trying to ensure that their short-term priorities do not damage their set long-term value. Healthcare sector leaders must consider the future by expanding their responsibilities. A shift away from the status quo is necessary for the healthcare industry. The healthcare industry is increasingly required to deliver high-quality, full-access, affordable, and sustainable healthcare services (Word Economic Forum, 2013).

The first dominant challenge experienced in South Africa's healthcare industry is delivering quality healthcare services. This challenge places much pressure on the industry because receiving quality health care is a constitutional right of the citizens of South Africa (Stuckler *et al*., 2011). Therefore, governments have made significant changes to healthcare policies and legislation to ensure that it complies with the delivery of quality healthcare. However, healthcare services have failed to meet patients' basic standards of care. The general patient's experience was also not at the desired level. These two factors have resulted in the public losing their trust in the healthcare system (National Department of Health, 2011). Although multiple efforts have been made after the 1994 elections to ensure the delivery of higher quality healthcare services, several challenges have been and continue to be experienced in the healthcare sector. The challenges experienced include but are not limited to prolonged waiting times due to limited human resources, already high and yet increasing costs, the lack of medical equipment and resources, and poor record-keeping (Maphumulo & Bhengu, 2019).

Sustainability is a concept that is relatively new to the healthcare industry, but its popularity has proliferated in the past two decades (Altpeter *et al*., 2014). The health systems that are currently operating are fundamental to achieving a high level of social health and welfare. High levels of social health and welfare in health systems are also critical factors required for development and economic growth. Due to the rapid growth in and the current size of operations, the healthcare sector consumes vast amounts of energy and resources, which directly and indirectly leads to the production of large streams of emissions and waste. The need for action is supported by the fact that environmentally sustainable intervention strategies can assist in tackling the sustainable construction and management of healthcare facilities, the design of sustainable healthcare processes, and the promotion of daily sustainable practices in the healthcare industry (Lopes *et al*., 2015). Increasing global and local healthcare systems' economic-, social-, and environmental sustainability is expected to significantly eliminate waste and attain various sustainable development goals (SDGs).

Waste in healthcare can range from physical medical waste to non-value-adding activities that increase patients' costs (Radnor, 2011). Sustaining lean implementations in healthcare has proven difficult because the improvements are often not maintained but return to their previous, non-lean state (Bateman & David, 2002; Kaye & Anderson, 1999). Authors estimate that between 66% and 90% of companies are unable to sustain their lean implementations (Bhasin, 2011; Bhasin, 2012). A significant body of literature has focused on developing sustainable healthcare systems. However, significant challenges in terms of economic-, social, and environmental challenges remain evident in healthcare systems across the world. In certain areas, healthcare is deemed unsustainable as a socio-technical system (Prowle & Harradine, 2015). From a theoretical perspective, there is a knowledge gap in the combined focus areas of this research, as illustrated in Table 47 in Appendix A, i.e., healthcare, sustainable transitions, sustainability transitions, and lean or lean thinking. Table 47 and Figure 48 in Appendix A show the growing popularity of sustainability in healthcare. However, incorporating lean thinking in sustainable transitions in healthcare is limited. Table 48 indicates the need for more research in South Africa because this research will be conducted to assess South African healthcare. The lack of research in South Africa highlights the need for this research to be conducted.

1.2 PROBLEM STATEMENT

Literature has demonstrated a global need to meet the SDGs (United Nations, 2022). Various analyses have been conducted on socio-technical transitions to understand how societal systems, including healthcare systems, can be configured to achieve increased sustainability and reach sustainability goals. These analyses to understand socio-technical transitions include the multi-level perspective (Geels, 2003), innovation systems approach (Edquist, 2005), strategic niche management (Schot & Geels, 2008), transition management (Elzen *et al*., 2004), and transition pathways (Geels *et al*., 2016). Socio-technical transitions have become a demanding topic of global sustainability debates (Köhler *et al*., 2019). Given this global sustainability problem, methods, and approaches to support the transition towards sustainability are required to ease the transition process (European Commission, 2020).

The problem that this research aims to address can be considered from two perspectives. The practical perspective considers that there are multiple challenges in the healthcare industry, including unsustainability, which can be solved using multiple solutions. Preliminary research indicates a need to identify and understand how sustainability transitions in healthcare can be supported (Broerse & Grin, 2017). Research has proven that lean thinking and sustainability align in terms of objectives and achieving the primary goal of processes (Khodeir & Othman, 2016). The technical perspective considers that there is a knowledge gap regarding the implementation of lean thinking to support sustainability transitions in healthcare. The current literature resources about the implementation of lean thinking to support sustainability transitions in healthcare are limited. It is especially scarce in a South African healthcare systems context, thereby highlighting the need for this research to be conducted.

1.3 RESEARCH AIM AND OBJECTIVES

This study aims to develop research products based on lean thinking to facilitate and support sustainability transitions in healthcare.

The research objectives (RO) of this study are:

RO1 Review and analyse literature about sustainability and socio-technical transitions, healthcare, lean thinking, sustainable healthcare, and lean healthcare to:

- RO1.1 Identify the lean challenges being faced in healthcare;
- RO1.2 Identify the extent to which lean thinking has been incorporated into healthcare;
- RO1.3 Identify the extent to which sustainability transitions have been incorporated into healthcare;
- RO1.4 Identify the extent to which lean thinking has and can contribute towards sustainability transitions in healthcare;

RO2 Develop a set of requirement specifications that guides the development of research products that facilitate and support lean thinking in sustainable transitions in healthcare;

RO3 Determine a set of intervention strategies that can aid in accomplishing the determined requirement specifications;

RO4 Develop research products to facilitate lean thinking in sustainable transitions in healthcare, with an operationalisation strategy of the research products. The operationalisation strategy will make use of a synthesised index that indicates which lean thinking approach or principle could support the respective sustainability transitions;

RO5 Evaluate the developed research products by conducting verification and validation to evaluate the theoretical correctness, practicability, usability, applicability, and whether the research products are fit for their intended purpose as stipulated by the requirement specifications.

1.4 EXPECTED CONTRIBUTION

This research is expected to contribute to the knowledge gap of lean thinking in sustainability transitions in healthcare. Furthermore, the study is expected to interrogate the extent to which lean thinking has been incorporated into health and care systems to support sustainable transitions. This research also contextualises how implementing lean thinking in the healthcare industry can contribute to sustainability transitions. The parties who could benefit from this research include the healthcare sector or healthcare professionals seeking to embark on more lean sustainable operation methods in their operations.

1.5 RESEARCH STRATEGY AND APPROACH

Mouton (2001) provides a research design typology that assists with planning this research study. This study takes on a non-empirical research approach and can be described as a “theory-building” study. This study is deemed a non-empirical research study because it seeks to explore, observe, and review existing literature in different areas of the research fields. A "theory-building" study implies that this research is used to develop new tools, models, frameworks, and theories or to refine existing tools, models, frameworks, and theories (Mouton, 2001). This research study synthesises the reviewed literature to develop a framework (i) to identify and define the role of lean in sustainability transitions, (ii) to develop an index that indicates which lean thinking approach or principle supports which sustainability transition, and (iii) the operationalisation strategy of the framework.

As illustrated in Figure 1, a systems engineering approach is followed, allowing for an extensive selection of possible approaches that transform the customer's operational needs into solutions. Systems engineering approach is selected because it transforms needs into suitable solutions while considering sustainable methods (United States Government, 2001). As illustrated in Figure 1, a systems engineering approach is followed, allowing for an extensive selection of possible approaches that transform the customer's operational needs into solutions. Systems engineering approach is selected because it transforms needs into suitable solutions while considering sustainable methods (United States Government, 2001).

1.5.1 INPUT IDENTIFICATION

The input identification phase identifies and contextualises key factors by consulting literature. This study's key factors include lean and lean thinking, sustainability and sustainable transitions, and healthcare.

1.5.2 REQUIREMENT ANALYSIS

The second phase of the systems engineering approach consists of the requirements that translate what the customer wants the system to do and how well it must perform. The requirements specifications are identified by consulting literature and are verified by consulting subject matter experts (SMEs). The verified requirement specifications are used to develop the tool that will support the aim of this study.

1.5.3 FUNCTIONAL ANALYSIS

The functional analysis phase consists of using the verified requirement specifications and identifying strategies that would address these requirement specifications. These strategies are identified by consulting literature and assist in providing a better understanding of what the tool implementation needs to accomplish.

1.5.4 DESIGN SYNTHESIS

The final phase is the design synthesis phase, which consists of developing and evaluating the tool that will assist in the aim of this study. The tool is evaluated to ensure its practicability and applicability to assist in solving the problem at hand.

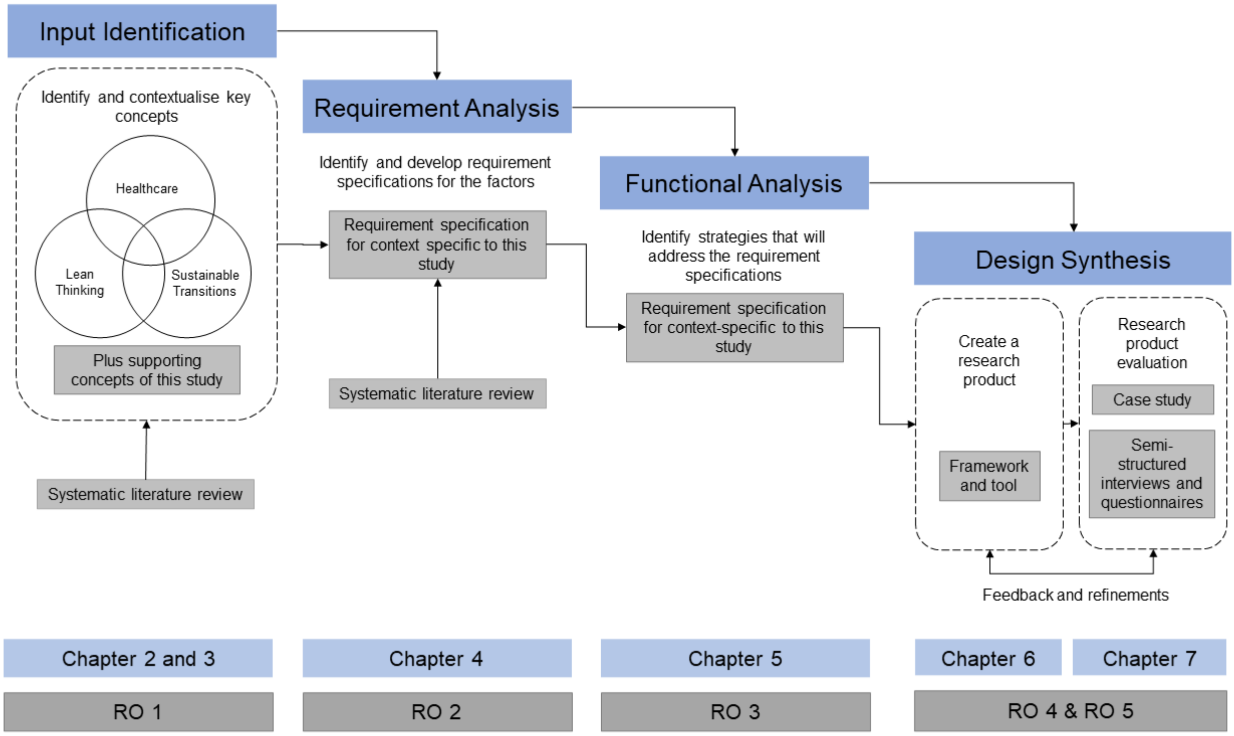


Figure 1: Adapted systems engineering approach (Huysamen, 2020)

1.6 RESEARCH SCOPE

The delimitations and limitations of this research are discussed in the following sections.

1.6.1 DELIMITATIONS

The following delimitations are highlighted:

i. The scope of this research focuses on the implementation of lean thinking within sustainability transitions in healthcare;
ii. This research focuses on integrating lean thinking and sustainability transitions in healthcare as a societal system. For this research, the term “societal system” refers to a system that has a societal function and undergoes sustainability transitions. The societal function transforms into a more sustainable state, achieves sustainability, or reaches sustainable development goals and targets. From research, it is understood that socio-technical systems are analytical approaches and descriptions of societal systems (Savaget *et al*., 2018); and
iii. The research considers lean thinking generally and not as a single approach or method.

1.6.2 LIMITATIONS

The following limitations are highlighted:

i. The scope of this research does not focus on healthcare for sustainable development;
ii. The scope of this research does not focus on sustaining lean in healthcare; and
iii. Design restrictions and boundary conditions presented in Chapter 4 also serve as limitations to the research products developed, which include:

a. The discipline of this research is Industrial Engineering. Hence the research products are developed from this perspective. SMEs could add other inputs from other disciplines in specific fields of this research;
b. The research products do not provide new meaning or theory around lean thinking and sustainability transitions. However, it integrates lean thinking into sustainability transitions in healthcare using theory and examples provided through literature resources;
c. The research products exclusively take a socio-technical transition perspective toward sustainability transitions;
d. The research products are most appropriate for the application to healthcare systems in the quest to fulfil sustainability targets and overcome challenges experienced in healthcare;
e. The research products must be utilised by users who possess some basic prior knowledge of the concepts at hand;
f. The research products cannot be applied without any contextual contributions from the users; and
g. The research products are exploratory in their application and are not to be used as a prescribed method to integrate lean thinking in sustainability transitions in healthcare.

1.7 DOCUMENT STRUCTURE AND OUTLINE

This section provides a document layout that reflects the logical course of this research study. A graphical illustration of the layout is presented in Figure 2 below, which depicts how the different chapters in this study align with one another. Each chapter includes an introductory paragraph and ends with a chapter conclusion. In addition, the arguments and motivation behind each chapter are summarised.

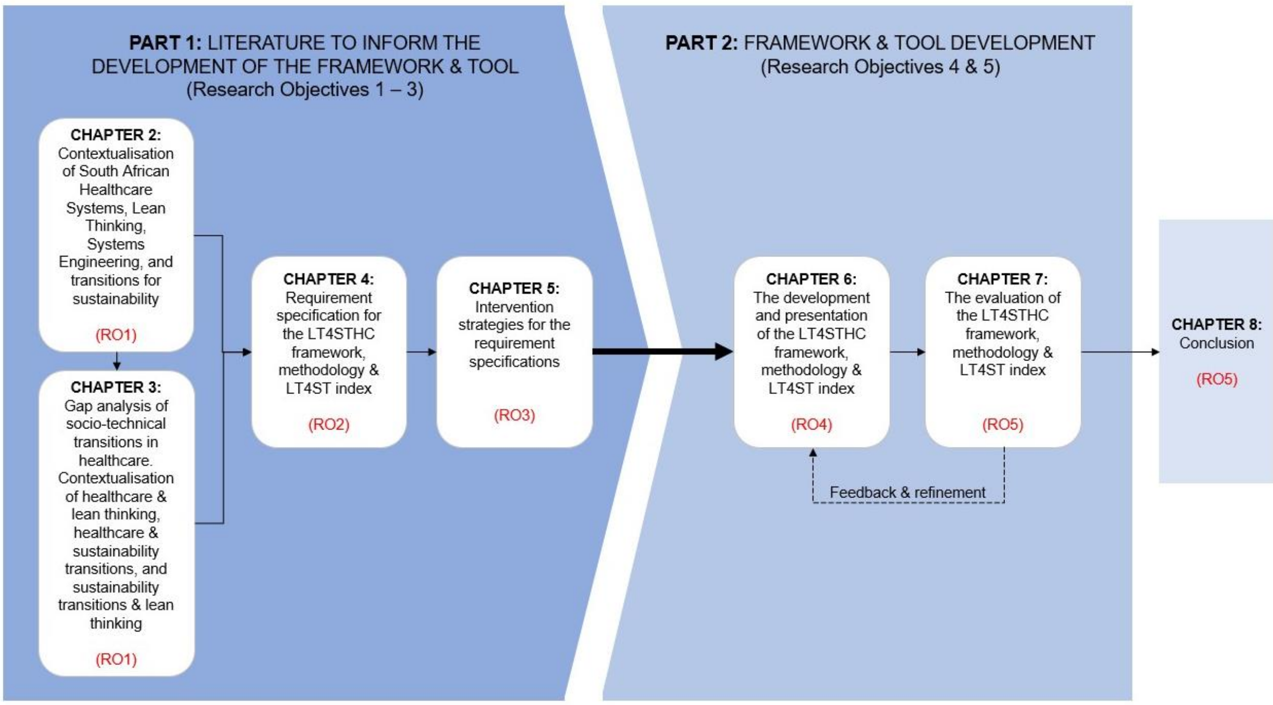


Figure 2: A graphical representation of the design and composition of this study

Chapter 1: Introduction

This chapter highlights the motivation for this research problem and study. It highlights the foundation from which the purpose and significance of this research are understood. It acts upon the notion that limited existing literature, frameworks, and tools use lean thinking to support and facilitate sustainability transitions in healthcare. It also highlights that no such approaches exist in the context of healthcare systems. The multiple facets of this challenge and an analysis of the research objectives are discussed, followed by the research approach, research scope, and document layout and design.

Chapter 2: Contextualisation of Healthcare, Sustainability Transitions, and the Concept of Lean

South African healthcare is investigated in terms of the current level of transitioning to sustainable development through sustainability transitions. This chapter provides context to this study by investigating South African healthcare systems, lean thinking, systems engineering, and transitions to sustainability. The literature in Chapter 2 is a guide towards achieving the facilitation of sustainability transitions in healthcare by implementing lean thinking approaches and principles. The literature in Chapter 2 provides direction for the investigation in Chapters 3 to 5.

Chapter 3: Content and Gap Analysis

This chapter explores the availability of published literature regarding socio-technical transitions in healthcare. It further elaborates on the three focus areas, i.e., healthcare, sustainability transitions, lean thinking, and their interrelatedness. These elements and components constitute the development of the framework, methodology, and index that will support sustainability transitions in healthcare by using lean thinking approaches and principles. These enabling factors and components are analysed, synthesised, and linked to understand how lean thinking can support sustainability transitions in healthcare.

Chapter 4: Requirement Specifications

In this chapter, the literature from Chapters 2 and 3 is utilised to establish the requirement specifications to which the proposed framework, methodology, and index should adhere to solve the problem highlighted by this research. The requirement specifications are provided in five categories: functional requirements (FR), user requirements (UR), design restrictions (DR), attention points (AP), and boundary conditions (BC). Consequently, different research product options are considered and compared. A framework is selected as the most suitable research product option to address the aim of this research study.

Chapter 5: Transition Approaches

A framework is utilised to implement lean thinking to support sustainability transitions in healthcare. Consequently, this chapter explores intervention strategies that could be utilised to achieve the set-out requirement specifications in the previous chapter.

Chapter 6: The Lean Thinking for Sustainability Transitions in Healthcare index, framework, and methodology

This chapter uses the literature and information from Chapters 2 to 5 to develop the proposed framework, methodology, and index. The framework, methodology, and index aim to support the implementation of lean thinking approaches and principles in sustainability transitions in healthcare. The development of the approach is guided by the requirement specifications as outlined in Chapter 4. Following the development, the LT4ST index, LT4STHC framework and methodology are presented.

Chapter 7: Evaluation Process

The verification and validation of the developed framework, methodology and index are conducted in this chapter. The first step in the evaluation process verifies the set of requirement specifications that was developed in Chapter 4. The evaluation process theoretically verifies the approach through subject matter experts, resulting in the refinement of the LT4STHC framework, methodology, and LT4ST index, which is then subjected to validation. The refined framework, methodology, and index's applicability, practicability, and usability are presented during the validation process through a case study application.

Chapter 8: Conclusion and Future Work

The final chapter provides a summary of the chapters mentioned above, how they contribute towards the development of the research products, and how they contribute towards the research objectives of this study. The key findings from the application of the developed framework are presented. A reflection on the research study follows, wherein the contributions and limitations are discussed. Finally, identification and discussion of possible future research are presented.

1.8 CHAPTER 1: CONCLUSION

This chapter provides background on the project and a literature analysis regarding lean sustainable healthcare. The research objectives and problem statement are presented. The next chapter, Chapter 2, will contextualise this research's niche concepts.

CHAPTER 2: CONTEXTUALISATION OF HEALTHCARE, SUSTAINABILITY TRANSITIONS AND THE CONCEPT OF LEAN

In this chapter, the input identification phase in the systems engineering approach is discussed. A graphical representation of the input identification phase is depicted in Figure 3. The discussion includes identifying and contextualising the niche concepts related to this study: healthcare, sustainability transitions, and lean thinking. This chapter will discuss the three key factors and provide an in-depth contextualisation. The contextualisation of healthcare, sustainability transitions, and the concept of lean is presented to fulfil RO1 (refer to Section 1.3).

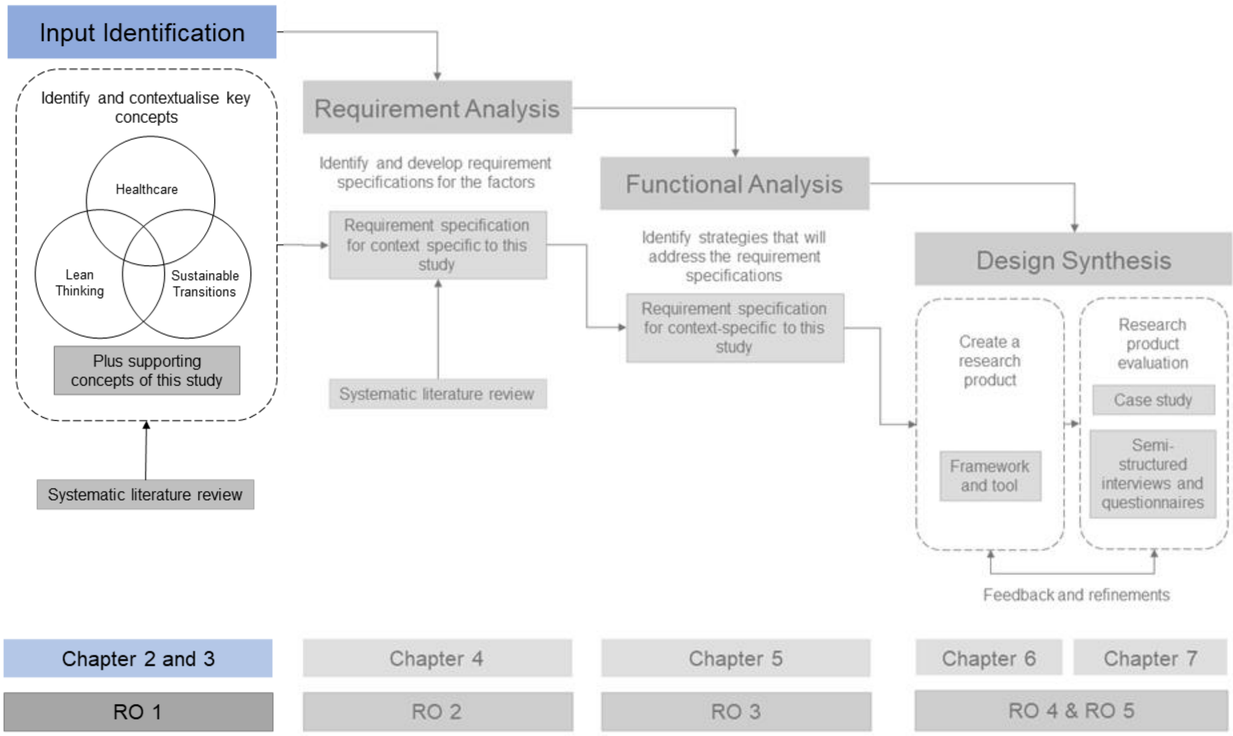


Figure 3: Input identification of adapted systems engineering approach

2.1 SOUTH AFRICAN HEALTHCARE

An overwhelming amount of evidence suggests that the quality of healthcare in South Africa has been compromised due to challenges impacting the quality of healthcare negatively. The improvement in the quality of healthcare implies that fewer errors are made, delay time on delivery is decreased, efficiency is improved, market share is increased, and costs are decreased. The evident decline in the quality of South African healthcare systems has caused the public to lose trust in the healthcare system (Maphumulo & Bhengu, 2019).

According to the World Health Organisation (WHO) (2012), health is a "*state of complete, physical and social well-being and not merely the absence of disease or infirmity*". This definition has created controversy due to the lack of value it adds to healthcare operations and the use of the word "complete". However, this definition has remained timeless and applicable throughout history

(Callahan, 1973). On the other hand, healthcare is described as "*the prevention, treatment, and management of illness and the preservation of mental and physical well-being through the services offered by the medical and allied health professions*" (Medical Dictionary, 2012).

The healthcare industry is under increasing pressure to operate with limited resources available (De la Maisonneuve & Oliveira Martins, 2014). Healthcare costs are increasing rapidly, more so than other product or service industries. The rising healthcare costs result from the healthcare industry being under constant pressure to impose drastic measures to improve services and general patient safety while simultaneously reducing costs, waiting times, and errors (Costa *et al*., 2015). Communities are changing their expectations regarding the reduction of energy consumption and the environmental improvements the healthcare industry should facilitate. Hospitals are complex institutions that consume about three times more energy and water than residential buildings of the same size. A study at John Hopkins University indicated that hospitals generate two million tons of waste annually, making them the second-largest waste producers (Cantlupe, 2010). Hospitals have a considerable influence in terms of social impact due to their geographical location. For example, the location of a hospital increases the traffic, noise levels, and other means of transport around the hospital precinct (Bottero *et al*., 2016).

Healthcare professionals and decision-makers recognise that innovative implementation strategies can be used to aid in these challenges to increase the quality, safety, and effectiveness of patient care (Department of Health, 2018). Healthcare services consist of continuous learning and relearning through trial-and-error processes. By gaining patient information, healthcare professionals determine a suitable diagnosis and treatment regime. Continuous learning and relearning through trial-and-error processes make healthcare services unpredictable, emergent, and continuously changing (Kritchanchai *et al*., 2017; Engelseth & Kritchanchai, 2018).

South African healthcare systems are highly unequal and are considered two-tiered. Public healthcare is funded by the state but caters to 71% of the population. Private healthcare is funded by individual contributions to medical aids and healthcare insurance and caters to 27% of the population. The public healthcare sector is underfunded, and most South African citizens cannot afford private healthcare. This inequity contributes to the inefficiency of South African healthcare systems (Rensburg, 2021).

2.1.1 CHALLENGES THAT COMPROMISE QUALITY IN SOUTH AFRICAN HEALTHCARE SYSTEMS

According to research, a few challenges have been identified which contribute to the compromise of the quality in the South African healthcare systems:

2.1.1.1 PROLONGED WAITING TIME DUE TO A LACK OF HUMAN RESOURCES

The lack of human resources is a significant weakness contributing to the low levels of quality in healthcare systems. It is said that Africa has less than one healthcare worker per 1000 population, which is significantly lower than the 10 per 1000 in European healthcare systems (Fonn *et al*., 2011). The quality of healthcare is worsened by the unequal distribution of healthcare professionals between the public and private healthcare sectors in South Africa (Barron & Padarath, 2017). A study was conducted that determined the experiences of chronic patients pertaining to the long waiting time at a community healthcare care centre in the Western Cape. The study revealed that the insufficient and inadequate number of healthcare workers, who also experience physical and mental exhaustion, contribute to the further deterioration of the quality of the healthcare systems (Tana, 2013).

2.1.1.2 ADVERSE EVENTS

Incidents have been reported where patients developed complications because they were denied access to healthcare services or turned away from public healthcare facilities. Many examples are evident in the literature about this problem within the South African healthcare systems (Sunday Tribune, 2015; Kama, 2017).

2.1.1.3 POOR HYGIENE AND POOR INFECTION CONTROL MEASURES

Numerous shortcomings are evident in South African healthcare systems, including long waiting times, poor-quality healthcare delivery, old and poorly maintained infrastructure, and poor disease control and prevention practices (Young, 2016). Literature provides evidence that most facilities have problems which include poor waste management, a lack of cleanliness, and poor maintenance of the grounds and equipment. Patients and staff also confirm that specific departments have unacceptable physical environments, which, for example, include dirty toilets and bathrooms (South African Medical Association, 2015; Nevhutalu, 2016).

2.1.1.4 INCREASED LITIGATION BECAUSE OF AVOIDABLE ERRORS

An increase in medical negligence litigation cases against the Department of Health has been reported. The growing number of lost cases leads to large numbers of payouts to patients. These settlements place even more strain on the healthcare budget in South Africa. Health Minister, Dr. Aaron Motsoaledi (2015) stated that "*the nature of the crisis is that our country is experiencing a very sharp increase – an explosion in medical malpractice litigation – which is not in keeping with generally known trends of negligence or malpractice*" (Kollapen *et al*., 2017). The South African Nursing Council also reported an increase in misconduct cases against nursing staff, which indicates that the rights of the patients and their families are being violated (National Department of Health, 2013).

2.1.1.5 SHORTAGE OF RESOURCES IN MEDICINE AND EQUIPMENT

Members of the public reported to Times Live (2018) that a shortage of equipment in hospitals leads to delays in urgent surgeries. Work is backlogged, which increases the delay even more for some patients waiting to be treated. Exposure to such long waiting periods before treatment or surgery commences causes some patients to develop complications or pass on. The report also stated that public hospitals in South Africa had become a "death trap for the poor" (Timeslive, 2018). A study conducted by Mokoena (2017) indicated that the lack of material resources, equipment, and supplies results in prolonged patient care being required (Mokoena, 2017).

2.1.1.6 POOR RECORD-KEEPING

The lack of effective record-keeping in South African healthcare systems causes unnecessary delays for patients. In the worst cases, patient information has been lost. Lost patient folders lead to the patients having to wait longer for admission, treatment, or surgery than is desirable. Lost patient data has, in certain instances, led to incorrect diagnoses and, in some cases, resulted in the death of patients (Kama, 2017).

2.1.2 SOUTH AFRICAN HEALTHCARE AND SUSTAINABILITY

Climate change is globally recognised as a growing global healthcare threat and amplifies the environmental risks to health. Healthcare systems should be the desired outcome. Factors such as energy and water consumption to toxic and plastic waste disposal should be prioritised to decrease the negative environmental impact (Irlam, 2021; Karliner, 2020).

According to the discussions held at the 17th Health Quality Assessment (HQA) on 5 August 2021, South Africa needs more equitable, resilient, and sustainable healthcare systems. During this conference, Professor Glenda Gray, President and CEO of SAMRC, stated that managing healthcare systems is a balancing act between saving lives and saving livelihoods.

The South African healthcare sector is a significant contributor to global-warming greenhouse gases and is vulnerable to climate change due to water shortages, high levels of disease infections, endemic poverty, and deep inequalities. The South African healthcare sector has a significant climate impact but also substantial mitigation potential. South African climate policies and plans recognise a need for a larger capacity in climate change awareness. South African climate policies and plans urge healthcare professionals to be highly trained as leaders who are rapid climate action and sustainable healthcare system activists (Department of Health, 2018; South African Medical Association, 2015).

2.2 LEAN THINKING

Lean is a popular methodology in the manufacturing industry, but it is not frequently used in healthcare (D'Andreamatteo *et al*., 2015). A lean methodology is an approach to systematically eliminating waste within a process or production system (Dondofema *et al*., 2017). Liker's lean (2004) describes 14 principles based on 20 years of studying and examining Toyota, one of the top-performing car manufacturing companies. As illustrated in Figure 4, these principles are the baseline for the Toyota Production System (TPS), a combination of socio-technical systems consisting of management practices and philosophies (Ohno, 1988).

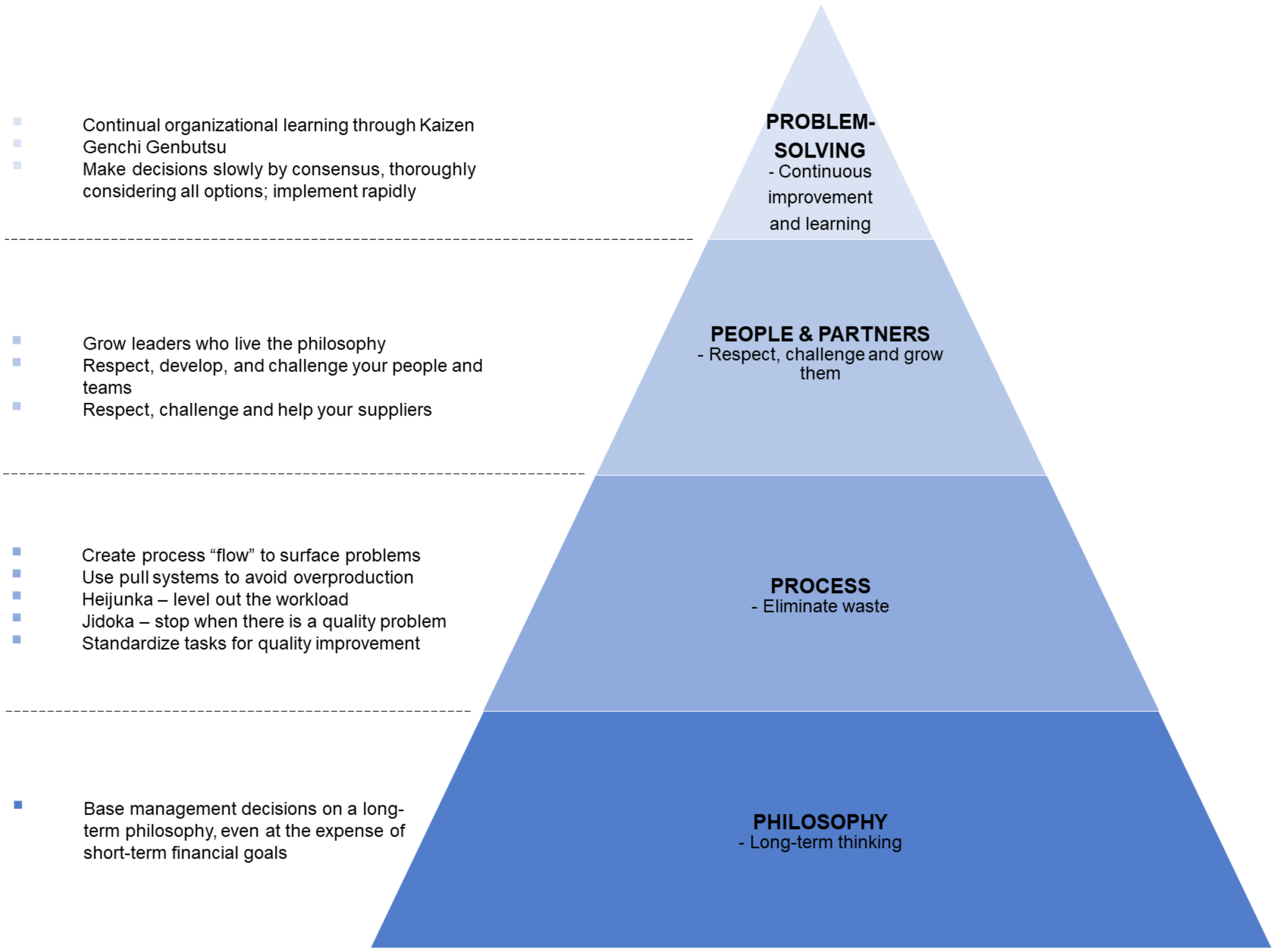


Figure 4: 4P Model of the Toyota Way & Liker's Lean (Liker, 2004)

Lean is a concept that can be explained in several ways (De Souza, 2009; Pettersen, 2009). Lean is an approach that focuses on improvement. By aligning specific actions that create value in the best possible sequence, lean actions can be performed effectively without interruptions (Costa *et al*., 2015). Lean tools' effectiveness depends on their ability to develop and sustain a culture that supports continuous improvement (Holweg & Pil, 2001). Most lean assessment methodologies set specific goals for the level of use of lean tools. However, this method is flawed because lean implementation is an ongoing continuous improvement process (De Treville & Antonakis, 2006). Womack, Jones, and Roos (1990) stated that improvements need to be sustained to become current states. The new current state, therefore, becomes the baseline for further improvements to reach a higher level of performance. The implication is that lean implementation creates a "never-ending cycle of improvement". Lean is a frequently used methodology in the manufacturing industry, but it is novel in the healthcare industry (D'Andreamatteo *et al*., 2015).

According to Womack *et al*. (2007), lean implementation provides opportunities to create a positive and fulfilling working environment. The increased level of employee involvement, ownership of problem-solving and improvements, diversified work functions requiring various skills and abilities, and increased cross-functional and inter-organisational functions can positively impact the work environment.

2.2.1 EIGHT MODERN WASTE TYPES

Despite the link between the deployment of lean processes and the effect of this journey, it is important to distinguish between the implementation and outcome of an assessment tool. Most lean assessment tools focus on outcome measurements instead of the lean journey (Liker, 2004). Taiichi Ohno (1988) defined a model with seven general waste types evident in the manufacturing industry, which have been transformed into eight modern waste types. The seven general waste types correlate with the NHSI Institute for Innovation and Improvement's examples of healthcare waste. These waste categories, types, and examples are discussed in Table 1 below.

Table 1: Types of waste (Ohno, 1988)

Waste category	7+1 waste types defined by Ohno	NHSI waste type examples in healthcare
Transportation	Moving resources that are not required to perform an activity constitutes waste. The excessive movement of resources could lead to damage and defects, unnecessary work, more significant wear and tear, and exhaustion.	The movement of human resources to the opposite side of the room to pick up notes or results The use of central storage units where equipment is placed instead of placing the equipment at the place of use
Inventory	Excess inventory can lead to defects or damage, increased lead times, and the ineffective distribution of capital. All components, Work in Progress (WIP) items, and unfinished products are classified as inventory.	Excess unused inventory in warehouses Patients waiting to be discharged Medication that could expire Waiting lists
Movement/motion	Resources required for the processes are moved more than is necessary.	The excess movement of employees searching for documents The storage of materials and equipment away from the point of use The absence of basic equipment in the office results in the movement of human resources to fetch the required equipment.

Waste category	7+1 waste types defined by Ohno	NHSI waste type examples in healthcare
		The layout of the office or hospital is not consistent with the workflow.
Waiting (delay)	Waiting for the next step in the process due to waiting for equipment or materials and idle equipment.	Waiting for patients, results, regulations, medicine, doctors, and patient discharges
Overproduction	The production of excess products which are not currently required for the process to be completed.	Execution of unnecessary tests Repeating the same test several times
Overprocessing	The inappropriate processing arises from improper tool use or ineffective product design.	Obtaining and requiring patient information several times during a single treatment. Repeatedly fetching the same patient for treatments or consultations requires the patient to be in a different location each time. Ordering complex diagnostic imagery when a simpler method could suffice.
Errors/defects	The efforts made in checking, identifying, and fixing defects Defects also occur during a process when a product is not deemed fit for use.	The readmission of patients due to unsuccessful discharges or inauspicious effects, i.e., something went wrong with a patient's discharge resulting in them being re-admitted within 48 hours of discharge. Repetition of tests due to a lack of correct information
Underutilised talent of people	A lack of understanding of human capabilities, skills, and knowledge occurs due to inadequate training, poor incentives, not generating feedback, etc.	Ignorance, omitting staff, poor communication Employees who feel burnt out stop sharing ideas for improvement.

These events can all be defined as activities that do not assist in progressing the patient to the next step of their treatment. According to Ohno (1988), an effective way to identify and eliminate waste is to use Value Stream Mapping (VSM), which allows the user to identify and analyse the current state and design the future state of a process. VSM is an effective lean management method that visually displays the relationship between the steps in a production process while separating the value-adding and non-value-adding activities. VSM is deemed effective because it starts with the end-user in mind while working backwards from the end-user to the start of the production process (Ohno, 1988). Implementing a continuous improvement journey can be instigated by challenging all employees to identify waste in their daily routines and, thereafter, action on the elimination of such waste.

2.2.2 LEAN PRACTICES AND APPROACHES

The industrial globalisation of the healthcare industry has provided increased opportunities for cost-effectiveness and the promotion of quality in the development and growth of this sector. However, it leads to increased responsibilities regarding regulations and boundaries, resulting in zero waste (Khan *et al*., 2020). Despite having access to a limited resource pool, the healthcare industry should take economic, social, and environmental issues into account by adopting lean and green principles which enhance competitiveness sustainably (Siegel *et al.,* 2019).

2.2.2.1 MINDSET AND ATTITUDE

This fundamental aspect of the lean methodology consists of implementing methods and practices with a long-term commitment toward lean green practices. The majority of lean principle implementations fail due to a lack of understanding and communication. Therefore, it is essential to ensure that the cognitive dimension, applicable tools, and concepts are mastered. Researchers have determined that mindset and attitude are the key concepts determining the success of lean implementation (Zhan *et al*., 2018).

2.2.2.2 LEADERSHIP AND MANAGEMENT

To ensure a continual long-term lean investment in the employees and maintain their willingness towards the promotion of lean culture, the leadership in the organisation should commit as well. Leaders should have an in-depth understanding of the lean journey to ensure that a lean culture is manifested and that people with the required skills are in the correct positions to ensure a successful lean journey (Zhan *et al*., 2018).

2.2.2.3 EMPLOYEE INVOLVEMENT

According to Zhu *et al.* (2005), the success of lean implementation is determined by the level of effort from the employees in the organisation, which in turn will improve the environmental and business performance of the organisation. As a long-term approach, it requires permanent and devoted commitment, starting with the willingness to change. The core of the lean principle implementation is the development of human capital. The overall lean journey should be linked with employee development (Womack & Jones, 2003). Employees should be actively involved during the entire lean journey, especially during the initial planning and final execution phase (Zhan *et al*., 2018).

2.2.2.4 TOOLS AND TECHNIQUES

The implementation of lean tools and techniques has proven to increase the competitive advantage of the user as well as improve the state of the business' level of performance. Quality service and customer satisfaction are two of the strongest drivers of lean implementation, and they must receive preference during the lean journey. Lean tools and techniques improve performance and contribute to increased sustainability without decreasing ecologically based efficiency (Thanki *et al*., 2016). These tools and techniques are identified as lean thinking, which "*aims to identify and remove waste with optimisation of resource utilisation*". The most common and influential lean tool is the 5S (sort, set, shine, standardise, sustain) tool, with an added sixth category that pertains to safety. In combination with value stream mapping, this tool is the most applied lean tool (Chiarini, 2014). The United States Environmental Protection Agency (2007) has developed and introduced a "toolkit" to provide environmental practitioners and lean operations managers with practical techniques which reduce business risk and cost and identify and eliminate waste (Zhan *et al*., 2018). Other lean implementation tools and techniques are:

i. Bottleneck Analysis;
ii. Overall Equipment Effectiveness;
iii. Plan-Do-Check-Act;
iv. Error Proofing;
v. Root Cause Analysis;
vi. SQDC (Safety, Quality, Delivery, Cost);
vii. A3 Lean Thinking Process;
viii. Waste Observation Chart;
ix. Process Flow Map;
x. Change management plan;
xi. Poka Yoke (mistake proofing);
xii. Hoshin Kanry (defines the company objectives under Lean principle);

xiii. Kanban (a mechanism to flow control and production control allowing the production of only what is needed at the moment when it is needed in quantity needed);
xiv. Andon (visual signal to inform when something is wrong or is in an abnormal condition); and
xv. SMED (Single-minute exchange of die, created by Shingo, reduce the setup times, complete as many steps as possible while the equipment is running or processing to save time and quickly change over to processing the next product).

2.2.2.5 SIX SIGMA

Six Sigma is a management approach that has grown as an addition to total quality management (TQM). The application of this approach, which has been implemented in healthcare systems, reduces the occurrence of defects in products and services. Six Sigma can also be defined as "*a statistical set contained with quality management for the construction of a framework for process improvement*" (Khan *et al*., 2020). It can also be defined as "*a customer-oriented, systematic, structured, multifaceted, proactive, business improvement quantitative philosophical approach to speed up deliveries, reduce cost, and to increase quality*" (Khan *et al*., 2020).

2.3 SYSTEMS ENGINEERING

The International Council on Systems Engineering (INCOSE) defines Systems Engineering (SE) as "*an interdisciplinary approach encompassing the entire technical effort to evolve into and verify an integrated life-cycle balanced set of system people, product, and process solutions that satisfy the customer need*" (Blanchard & Fabrycky, 1998; INCOSE, 2017).

2.3.1 FOUNDATION OF SYSTEMS ENGINEERING APPROACHES

SE is a process that uses technology in combination with management principles to form a well-planned and highly disciplined approach. The application of SE requires cooperation, focusing on the process, and developing a "new thought" (Blanchard & Fabrycky, 1998).

Although SE does not have a fixed definition, there are similarities in all the definitions, and that is that SE is a type of engineering that emphasises certain areas. Some of these are:

i. A *top-down approach* views the system in its entirety. Former engineering activities have covered the design of a system's components, representing a bottom-up approach. The "bigger picture" of a system is usually overlooked due to a lack of overview and understanding of how the components operate together;
ii. A *life-cycle approach* includes the development, design, production, construction, distribution, operation, maintenance, support, retirement, phase-out, and disposal of the system. In the past, emphasis was primarily placed on design and system acquisition. To adequately identify and mitigate risks of up-front decisions, such decisions need to be based on life-cycle considerations;
iii. A *definition of system requirements* related to specific design criteria. The follow-up analysis ensures the effectiveness of the decisions made during the early stages of the design process. System requirements need to be defined, specified, and traceable; and
iv. An *interdisciplinary approach* incorporated into the system design and development ensures that all objectives are addressed effectively and efficiently. Implementing the systems engineering process requires an in-depth understanding of different design disciplines and their correlations with each other in combination with other tools and techniques (Blanchard & Fabrycky, 1998).

The systems engineering approach combines all the approaches mentioned above to adequately study dynamic complex systems by isolating the system into smaller components (Situmeang, 2016).

Systems design is considered a "prime mover" of systems engineering, which requires iterations and integration that synchronises synthesis, analysis, and evaluation processes (Blanchard & Fabrycky, 1998). SE is a repetitive process which aims for optimised and efficient operations whilst ensuring that the operational and strategic actions of the company are met. The engineering aspect of SE entails the execution of tools or structured approaches that develop a product or service (Ahram & Karwowski, 2013).

2.3.2 SYSTEMS THINKING

Systems thinking is a new way of thinking primarily based on a system as a whole and the interrelatedness of the system components. According to literature sources, systems thinking is a non-novel idea that can be defined as a "scientific framework for understanding the change and complexity of a system as an interconnected whole rather than components in isolation through the study of dynamic cause and effect over time" (Lazanski, 2010; Maani & Cavana, 2007). Systems thinking takes a holistic approach to how different system components interact. Systems thinking thus controls economic, social, and environmental systems (Maani & Cavana, 2007). In systems thinking, the number of uncertainties is reduced by establishing clear performance indicators. Systems thinking is crucial for organisational success (Seiler & Kowalsky, 2011).

Systems thinking is applicable not only in any business activities or operations but also in understanding the complexity of everyday life, the growing need for interdependence, and the critical need for change management (Maani & Cavana, 2007). Systems thinking is tridimensional as it has three critical dimensions: paradigm, language, and methodology (Griffin *et al*., 2016). The paradigm is the way of thinking by seeing the "bigger picture" while acknowledging that matters are constantly changing within these paradigms, languages, and methodologies. It also entails gathering an in-depth understanding of the operations of activities while recognising that the outcome can impact the purpose of the system. The language dimension defines how activities should be executed according to specific rules. The language must be translated into visual perceptions, which emphasise the interdependence of the components in the system. The methodological domain entails incorporating learning technologies and other tools to aid in understanding the complex system at hand. The application of systems thinking approach to sustainability enables the user to gain a better understanding of the impacts of the system operations and avoid unintended consequences. It also allows for the exploration of opportunities for innovation and design approaches for system change (Griffin *et al*., 2016).

Systems thinking, as illustrated in Figure 5, consists of five principles: openness, purposefulness, multi-dimensionality, emergent property, and counterintuitive behaviours acting together as a whole. These principles define the characteristics and assumptions about the behaviour of an organisation that is viewed as a purposeful and multi-minded system (Gharajedaghi, 2011).

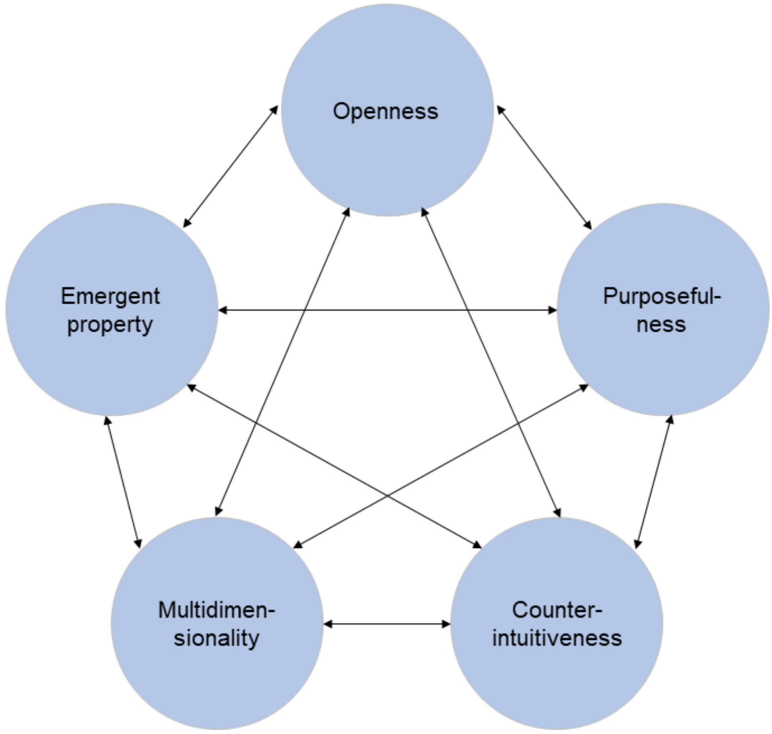


Figure 5: 5 Principles of systems thinking (Gharajedaghi, 2011)

Openness refers to the behaviour of open systems that can only be understood entirely in the context of their environment. This principle implies that there are elements of choice and uncertainty, but it must be made clear which elements are certain and which are chosen. The openness element supports the fact that all system components are interdependent. The behaviour of an interactive set of uncontrollable variables is, to a certain extent, predictable. These "*openness"* factors all contribute to the formulation of the first "rule" of systems thinking, i.e., *predict and prepare*, which ensures that open systems are understood (Gharajedaghi, 2011).

Purposefulness refers to understanding why the components in a system are doing what they are doing. In the past, it was sufficient to gain a competitive advantage by merely gaining information on a competitor. However, the modern take on competitive advantage is knowing why they do what they do. A purposeful system is a system that strives to achieve value, which often is indirectly incorporated into the culture of the organisation (Gharajedaghi, 2011).

Multi-dimensionality is defined as the ability to "*identify complementary relations in opposing tendencies and to create feasible wholes from infeasible parts*". Opposing tendencies can be conceptualised as two mutually exclusive and discrete variables and can be formulated in a way that they represent a continuum. This is where compromise comes into play to resolve conflict. The principle, however, remains that those opposing tendencies do not just coexist and interact but form a complementary relationship (Gharajedaghi, 2011).

The emergent properties (properties that arise through the interactions among the system components) become apparent and result from interactions between components in the system. However, they are not properties that belong to the components themselves. These are emergent properties of the whole system. Emergent (type II) properties are system properties as a whole and not the properties of the components of the system. Emergent properties are defined as "the product of interactions among several elements" (Gharajedaghi, 2011). It is not a one-time proposition, but it is reproduced continuously. These properties cannot be measured directly. The components of the system must be compatible to reinforce mutual interactions that unfold a force (Gharajedaghi, 2011).

The counterintuitive behaviour is highly evident in today's social dynamics. Counterintuitive behaviour is defined as "actions intended to produce the desired outcome that can generate opposite results" (Gharajedaghi, 2011). Counterintuitive behaviour is also illustrated by:

i. Societal systems that tend to repeat themselves and regenerate similar non-solutions on a repetitive basis;
ii. The occurrence of catastrophe theory (Zeeman, 1976) highlighted that the inflexion point is where the system typically displays "a cusp", which refers to catastrophic behaviour;
iii. The market usually selects the most satisfying and comparable solution, and not necessarily always the best one; and
iv. The passive adaptation that could lead to disaster if it is towards a deteriorating environment (Gharajedaghi, 2011).

Systems thinking has numerous advantages. The main advantage is that it effectively identifies solutions to challenging problems, which requires a higher thinking level.

2.3.3 THE SYSTEMS ENGINEERING APPROACH

The SE approach provides a plan for adequately unpacking a problem into functional subdepartments or units while understanding how each of the subdepartments interacts and contributes to the whole system (Porter, 1991).

As illustrated in Figure 6, the SE approach is based on the flow of real-world problem-solving. A complex system problem (Quadrant I) needs to be broken down into sub-problems (Quadrant II). The second quadrant ensures a deeper understanding of those identified sub-problems. Numerous sub-solutions are available to solve the identified sub-problems (Quadrant III), which in combination with each other, can serve as a solution to the problem as a whole (Quadrant IV). The pivotal part of the SE approach is to ensure that the main objective is reached. According to Snyman *et al.* (2014), the facilitation of feedback loops between the quadrants will aid in achieving the main objective.

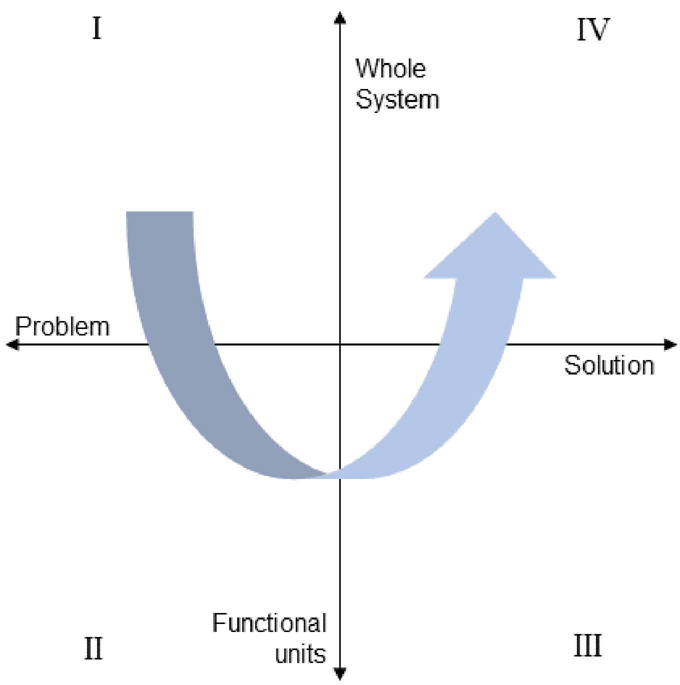


Figure 6: Flow of real-world problem solving (adapted by (Porter, 1991))

2.4 TRANSITIONS FOR SUSTAINABILITY

The European Environment Agency (2018) identified five perspectives in the approach of systemic transition towards sustainability. These perspectives include socio-economic, socio-ecological, action-oriented perspectives, integrated assessment models, and socio-technical approaches.

The socio-economic perspective addresses transitions to sustainability regarding two aspects of the economic paradigm. These aspects are market capitalism and economic sub-system analysis, which analyses the co-evolutionary process, including the change of production patterns, work relations, and work culture.

The socio-ecological perspective is a combination of elements of nature and society which aims at incorporating bio-physical and human social dimensions as part of the analysis of sustainability at different levels.

The integrated assessment model approaches transitions to sustainability from a quantitative perspective. This assessment model analyses the systemic changes in combination with frameworks and other methodologies from socio-technical, socio-economic, and socio-ecological approaches (European Environment Agency, 2018). The action-oriented perspective focuses on the roles of the actors who influence societal systems.

The socio-technical stance includes the understanding of complex and multifunctional systems. Socio-technical systems are designed to fulfil and satisfy societal functions and analyse how these systems are designed, transformed, and transitioned to meet sustainability goals and targets (European Environment Agency, 2018).

Activities and operations are sustainable if they fulfil economic and social development and environmental protection while meeting the needs in all three sustainability development dimensions (Kongoli, 2016). The socio-technical perspective and theories describe these transitions as a collaboration of efforts from various disciplines, specifically engineering, sociology, psychology, and computer science. Engineering has been linked to the hardware components of socio-technical transitions and theories. Disciplines such as Systems and Industrial Engineering include principles from other fields such as social science, business commerce, computer technology, science, and psychology. Collaboration from various disciplines is beneficial for Industrial and Systems Engineering as it provides a more holistic approach to socio-technical analysis and designs (Whitworth & Ahmad, 2013).

Socio-technical transitions are strongly correlated to concepts about sustainability and sustainable development (Baxter & Sommerville, 2011). It is a large-scale transformation of unsustainable socio-technical systems which involves long-term processes to effect changes to an alternative sustainable socio-technical configuration. These configurations target specific sustainability issues (Geels, 2011), and in this context, socio-technical transitions are often interchangeably referred to as sustainability transitions (Geels, 2011; Tran, 2014). Technology and society are vital components because they determine which socio-technical transition occurs, provide the required resources, and affect the change's dynamic toward sustainability (Baxter & Sommerville, 2011). The critical role of society in socio-technical transitions highlights the importance of considering economic, political, and social factors within the dynamics of socio-technical transitions. Incorporating technology and society in socio-technical transitions increases complexity as it adds stochasticity and variability to the system dynamics. The complexity of such a system is in contrast with a purely technological perspective, which is less complex. It is further argued that solutions to sustainability challenges cannot be achieved through the incremental development of technology. However, it needs to be incorporated in conjunction with all aspects of society (Tran, 2014).

The new field of transition research proposes that to become more sustainable, problems in any societal system require fundamental changes in the structures, cultures, and practices (Frantzeskaki & De Haan, 2009). Transition management (TM) demands a systematic development method, combined with the use of alternative societal niches which operate as key instruments to facilitate sustainability transitions (Frantzeskaki *et al*., 2012). Sustainability transitions are open-ended, non-linear, and uncertain and cannot be managed frequently. They require an iterative, reflective, and explorative way of management aimed at societal learning (Schäpke, 2014). When used as a governance approach, transition management facilitates programs and policies that directly link to sustainability. This is due to the rationale of this management approach and the design of the specific transition management instrument, which follows the basic principles of sustainability (Frantzeskaki *et al*., 2012).

Transition management as a governance approach is a recurrent process that consists of development at various levels (Loorbach & Rotmans, 2010). Four apparent types of governance activities can be identified when observing the behaviour of societal transitions:

i. *Strategic* - activities at the level of a societal system consider a long-time horizon, relates to the structuring of complex problems to create alternative futures;
ii. *Tactical* - activities at the level of a sub-system that relates to the build-up and breakdown of the structures in the system, often through means of negotiation, collaboration, etc.;
iii. Operational - activities which relate to short-term decisions and actions. These activities are evident at a level in the system where actors either recreate, restructure, or change the system structures; and
iv. *Reflexive* - activities that relate to evaluating the current situation at various levels and the interrelation or misfit of these activities. Through means of debate, structured evaluation, assessment, and research, societal challenges are constantly structured, reframed, and then dealt with (Hernández-Chea *et al*., 2020; Frantzeskaki *et al*., 2012).

As illustrated in Figure 7, each of the phases mentioned above relates to a different transition management instrument, which has been developed by transition scholars and tailored specifically for the objective of each phase. These instruments have been developed through practical experience. According to Loorbach and Rothman (2010), transition management phases do not require a fixed sequence and can differ in importance, depending on the cycle.

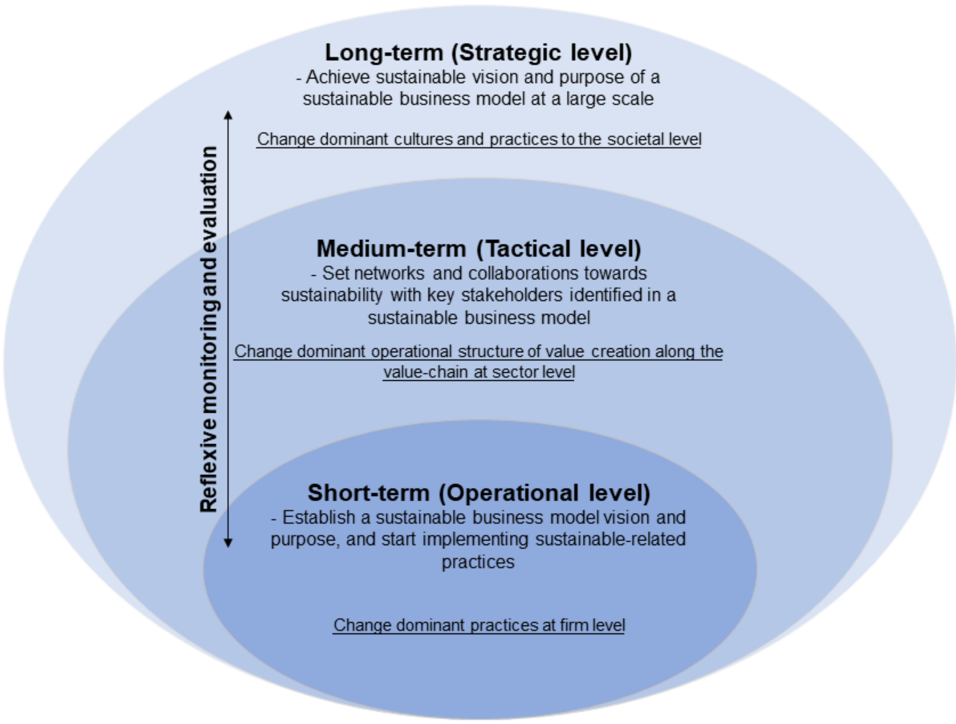


Figure 7: Transition management cycle and business model activity system for sustainability transitions (Loorbach & Rotmans, 2010; Frantzeskaki *et al*., 2012)

Transition management consists of the following phases:

i. Structuring the problem and then establishing and organising the transition area;
ii. Developing the transition agenda, which includes a vision of sustainable development and transition paths;
iii. Establishing and carrying out the transition experiments and assembling the resulting transition; and
iv. Monitoring, evaluating, and learning from the transition experiments. Thereafter, based on the findings, adjusting the vision, agenda, and related activities (Loorbach & Rotmans, 2010).

The main idea is that already existing or emerging transitions can first be identified and analysed through the transition's perspective, and thereafter, a strategy can be developed using the transition management cycle. Most transition approaches have been started by entrepreneurial policymakers and not as planned projects (Loorbach & Rotmans, 2010), which implies that a small start to the process is the most feasible due to its unpredictive nature.

Although there is an increase in the literature about lean in healthcare, the question lies in how lean has been incorporated into sustainability transitions to support these transitions from a socio-technical transition perspective.

2.5 CHAPTER 2: CONCLUSION

After an extensive investigation of the literature available about this study's key concepts, it is evident that there is a lack of research regarding the implementation of lean thinking in sustainable transitions in the healthcare industry. The healthcare industry is increasing the incorporation of lean thinking to eliminate non-value-adding activities. This chapter also highlights the need for a systematically developed framework which implements the holistic sustainability principles proposed under the concept of circular economy (CE) while benefiting from the strengths of other concepts, such as lean (Garza-Reyes, 2015).

CHAPTER 3: CONTENT AND GAP ANALYSIS

In this chapter, the input identification phase of the systems engineering approach is discussed. Firstly, a gap analysis is performed. Thereafter, the integration of the focus areas of this research is discussed. Figure 8 illustrates the integration of the focus areas relating to this study, namely, healthcare, sustainable transitions, and lean thinking. Other than discussing the interrelatedness of the three focus areas, an in-depth contextualisation of each focus area is addressed. The content and gap analysis are presented to fulfil the RO1 (refer to Section 1.3).

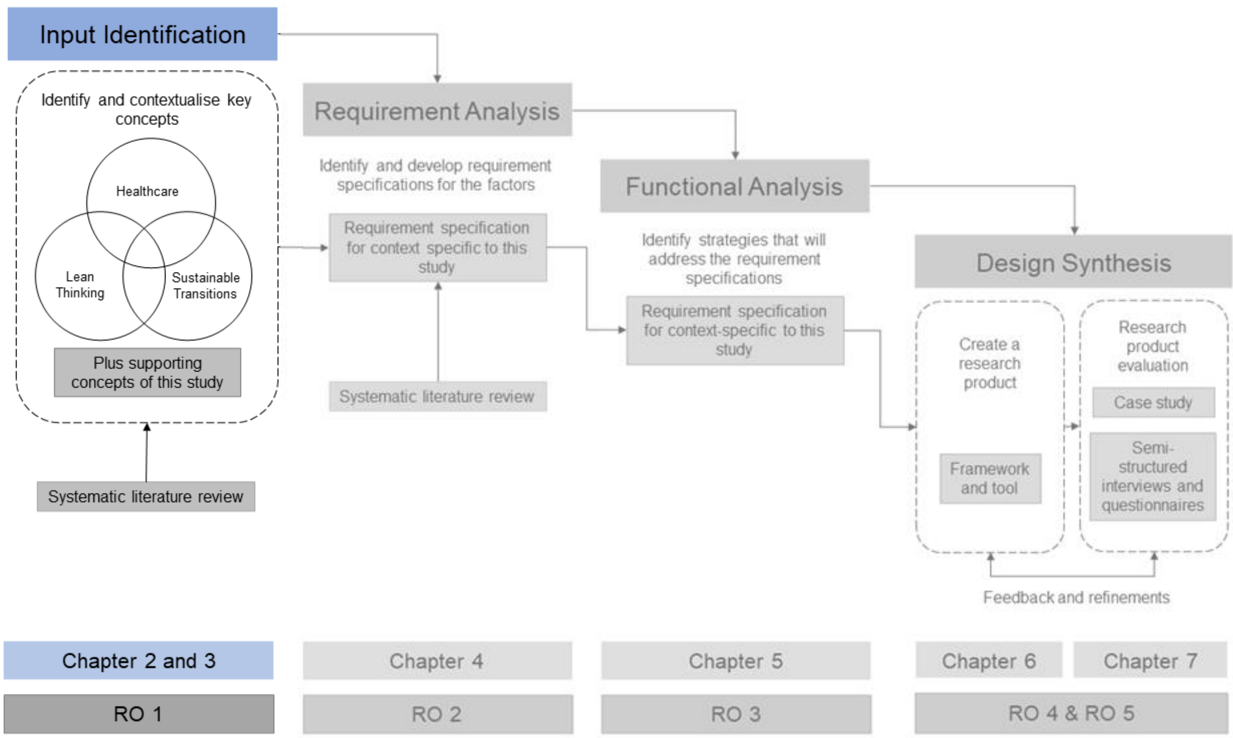


Figure 8: Input identification of adapted systems engineering approach

3.1 SYSTEMATIC LITERATURE REVIEW

A significant body of literature has focused on developing sustainable healthcare systems. The increase in global and local healthcare systems' social-, environmental- and economic sustainability is expected to contribute significantly to attaining various sustainable development goals. However, significant challenges in economic-, social-, and environmental challenges remain evident in healthcare systems across the world.

This section aims to assess the extent to which sustainability transitions have been incorporated into healthcare as a socio-technical system. The evaluation of sustainable transitions implemented in healthcare aims to add to the existing research on the transitions of healthcare systems into more sustainable states. The analysis illustrates the role of inter-institutional collaboration in ensuring sustainability in healthcare systems. The integration of various sustainability paradigms in healthcare literature and systems is contextualised based on an analysis and visualisation of content analysis. This section presents a bibliometric analysis of literature that considers the combination of the concepts of sustainability, sustainable development, socio-technical systems, and socio-technical transitions within healthcare.

Sustainability is not a new concept, but it continues to become increasingly popular due to the increase in the need to understand and acknowledge resource scarcity. The concept of sustainability emerged from demonstrations such as social justice, conservationism, internationalism, etc. By the end of the 20th century, these demonstrations collectively came together to be called “sustainable development”. Brundtland Commission released a definition in 1987, “*sustainability development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (Yu *et al*., 2020).

Sustainability is an approach that is deemed a holistic approach in which social, economic, and environmental aspects must be considered in conjunction with one another to find a lasting existence of prosperity (Ponnala & Rivera, 2019). Social sustainability is regarded as satisfying all people's universal human rights and basic needs, implying access to sufficient resources to keep communities healthy, secure, and functioning. In healthy communities, personal, labour, and cultural rights are considered, and individuals are safe from discrimination. Economic sustainability is defined as the ability of communities to maintain independence due to their access to sufficient resources to meet their needs. Environmental sustainability is regarded as the ecological integrity maintained by ensuring that all the environmental systems are balanced, ecological integrity is maintained, and environmental sustainability is accomplished. An environmentally sustainable earth implies that natural resources are replenished at a natural rate after humans consume them (Yu *et al*., 2020).

Sustainable healthcare systems are the gateway to providing higher quality, lower cost healthcare, reaching large populations and effectively managing diseases in a particular area (Heiskanen *et al*., 2009). Cost efficiency and the effectiveness of a healthcare system cannot be achieved simultaneously. Researchers have proven that there is an evident compromise between the increases that occurs between effectiveness and efficiency. The effectiveness of the sustainable healthcare system is an indication of the potential of the healthcare system to be able to achieve its maximum possible output (Pereno & Eriksson, 2020).

Sustainability and sustainable development are concepts that are directly related to socio-technical systems. Socio-technical systems are defined as the combination of technologies, infrastructure, industries, supply chains, and organisational responsibility to deliver a societal function (University of Alberts, 2016). Socio-technical systems have been analysed in the dimensions of environmental protection and affordability. The environmental and financial aspects of sustainability have increased the focus on reducing waste and emissions, developing new technologies, and “greening” of industrial ecosystems (Robert *et al*., 2005; Kuhlman & Farrington, 2010).

Sustainability is accomplished by transitioning socio-technical systems towards sustainability, i.e., socio-technical transitions/sustainability transitions. Socio-technical transitions operate at a societal level or function in the sectors of transport, energy, housing, agriculture, communication, and healthcare (Karamat *et al*., 2019). The term “socio-technical” refers to the co-evolution of social and technological relationships. In contrast, “transitions” refer to the dynamics by which the change in this specific relationship occurs (lo Storto & Goncharuk, 2017). Innovation and environmental studies within socio-technical regimes have become the focal point in numerous analyses. The increased focus on innovation and environmental studies recognises a need for drastic change to happen in the form of socio-technical transitions to deliver more sustainable development (Sorrel, 2018).

This section presents a bibliometric analysis of the extent to which socio-technical transitions have been incorporated into healthcare. In this bibliometric analysis, the author aims to highlight opportunities for further research regarding socio-technical systems in the advent of sustainability or sustainable development within healthcare.

Table 2 reflects the terms and combinations of terms utilised to conduct literature searches. Specific searches were conducted by using combinations of the search terms. These combined searches led to four labelled search combinations, as indicated in Table 3.

Table 2: Applied search terms used in SCOPUS

Key Term	Variations
Healthcare	Healthcare; health care
Socio-technical	Socio-technical; socio technical; socio-technical
Transition	Transition; transitions

Literature concerning sustainability or sustainable development, sustainable transitions, healthcare, and socio-technical systems was collected using SCOPUS. Specific search key terms were selected that relate to the concepts. The set of selected terms was further expanded to include variations of the key phrases to provide an accurate search. Table 3 indicates the key terms and the variations of the terms used.

Table 3: Search combinations

Searches	1	2	3	4
Socio-technical systems		x	x	
Sustainability transition(s)			x	
Socio-technical transition(s)				x
AND				
Sustainability OR sustainable OR sustainable development	x	x	x	x
Healthcare	x	x	x	x
Search combination (SC) label	**SC1**	**SC2**	**SC3**	**SC4**

The results which were obtained with the aid of SCOPUS are discussed in this section. In the comprehensive analysis, no exclusions were implemented, ensuring access to as much literature as possible was accomplished. In the following section, a discussion of the overall results of the searches, the analysis, and the inferences are presented. The following section focuses on the literature within this research's central areas of this research being, sustainability, healthcare, and socio-technical systems and transitions. The method mentioned above is used to determine whether sufficient research has been conducted regarding socio-technical systems and transitions, sustainability transitions, sustainability, and healthcare.

A SCOPUS search was conducted on a combination of search terms. The number of documents in which combinations of the search terms were found and the corresponding SCOPUS algorithm is displayed in Table 4.

Table 4: Documents obtained from SCOPUS

Search Combination Label	Scopus Algorithm	The number of documents obtained
SC1	(TITLE-ABS-KEY ("sustainability" OR "sustainable" OR "sustainable development") AND TITLE-ABS-KEY ("healthcare" OR "health care"))	26 111
SC2	(TITLE-ABS-KEY ("sustainability" OR "sustainable" OR "sustainable development") AND TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("socio-technical system*" OR "socio technical system*" OR "socio-technical system*"))	21
SC3	(TITLE-ABS-KEY ("sustainability" OR "sustainable" OR "sustainable development") AND TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("socio-technical system*" OR "socio-technical system*" OR "socio technical system*") AND TITLE-ABS-KEY ("sustainability" AND "transition*"))	3
SC4	(TITLE-ABS-KEY ("sustainability" OR "sustainable" OR "sustainable development") AND TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("socio-technical transition*" OR "socio-technical transition*" OR "socio technical transition"))	1

There is substantial literature about sustainability or sustainable development within healthcare. However, upon further investigation, it is evident that less literature is currently available when considering the search terms that are concentrated around this research topic, i.e., the extent to which sustainable transitions have been incorporated into healthcare as a socio-technical system. The following sections present an overview of a comparative analysis of the publications' timeline, the research's subject areas, and the publication origin areas between the search combinations (SC1, SC2, SC3, SC4).

A selection process chart is added, as illustrated in Figure 9, to indicate the acceptance of papers as possible aids to this section. This is an outline of the articles that were selected to support the theory behind the identified search combinations. Additional literature sources will also be used to assist this section. Figure 9 below is a visual illustration of the SCOPUS articles used for this section.

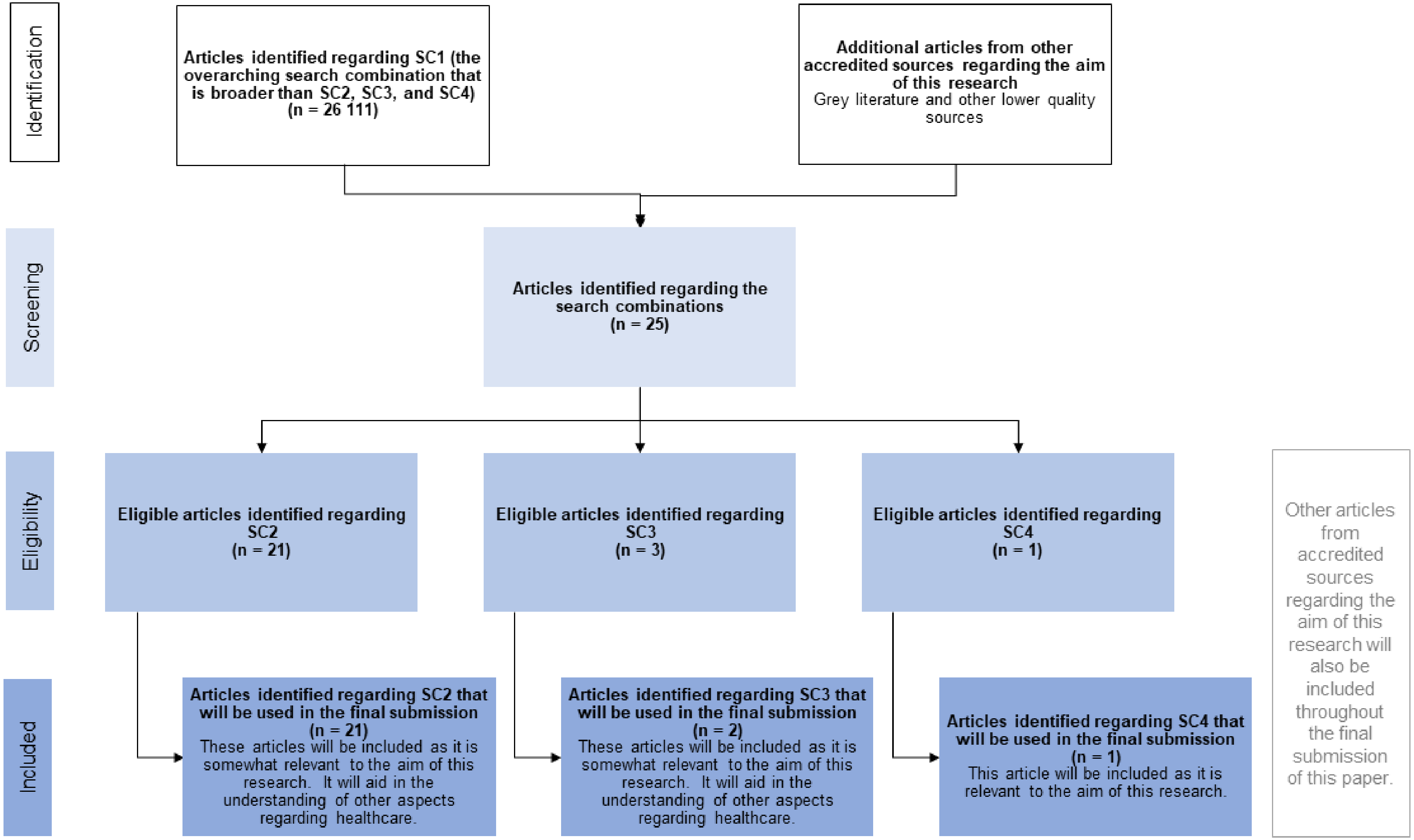


Figure 9: SCOPUS article selection

Figure 10, below, graphically represents the number of documents, incorporating the four search combinations, which have been published annually.

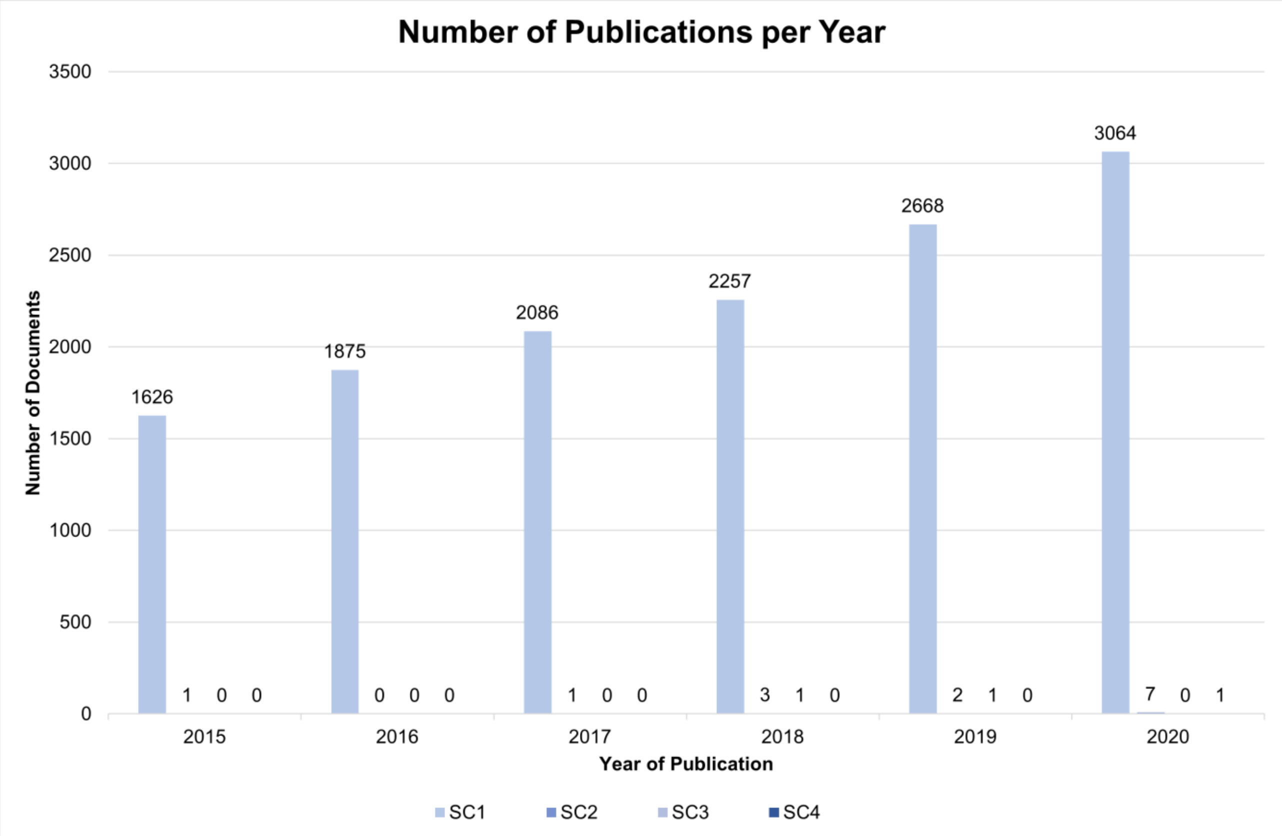


Figure 10: Documents published per year

Documents about sustainability and sustainable development within healthcare are increasingly becoming more popular. This specific chart type relays the pivotal information that there is a clear gap in research about SC2, SC3, and SC4. Furthermore, it is indicative that there needs to be more research regarding socio-technical systems, socio-technical transitions, and sustainability transitions within the healthcare industry.

Figure 11 below indicates the common subject areas within the search combinations. The most common subject area, overlapping all four search combinations are Social Sciences and Business, Management and Accounting. However, the two subject areas with the most published articles are Medicine and Social Sciences. It is also observed that the search combinations are mainly focused on the science field.

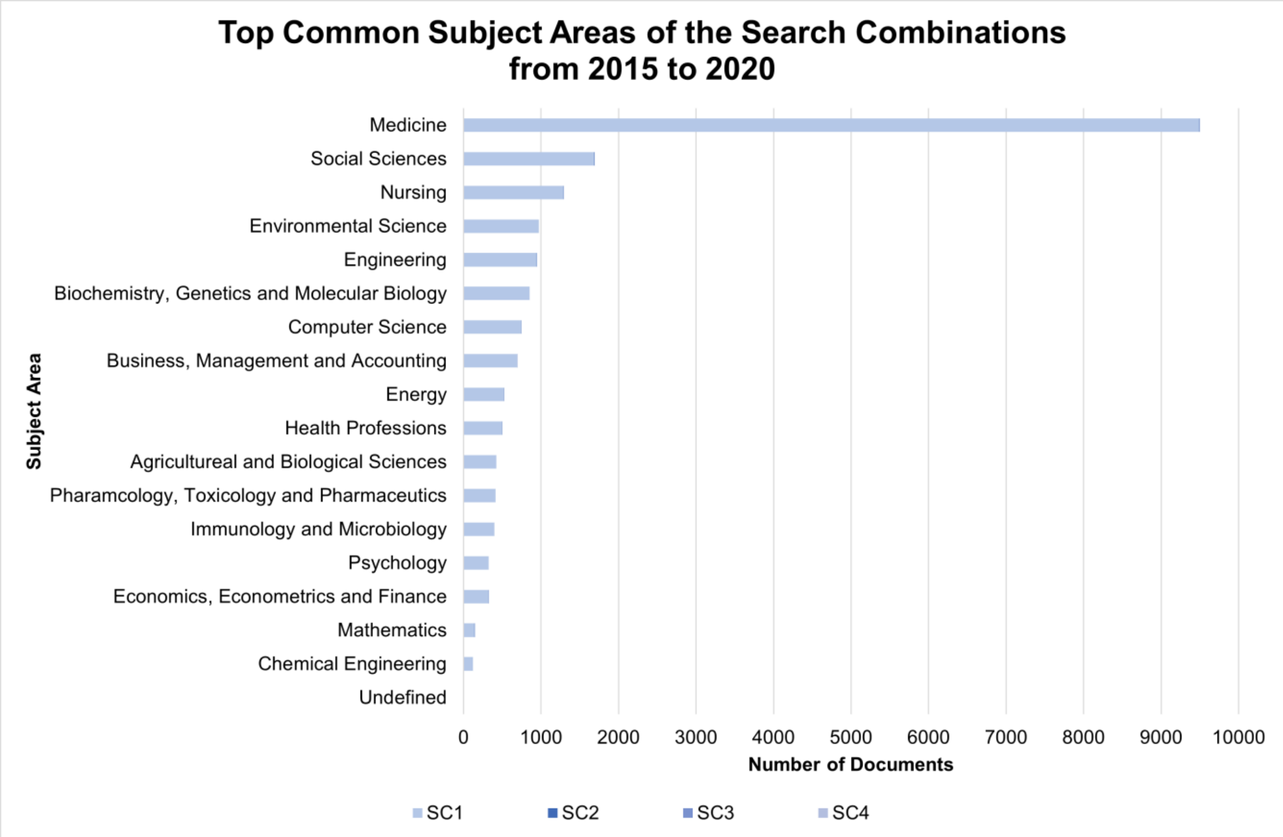


Figure 11: Common subject areas of the search combinations between 2015 and 2020

Most literature on search combinations originated in the United States and the United Kingdom. As seen in Figure 12 below, it is evident that there needs to be more research, based on the search combinations, from other regions.

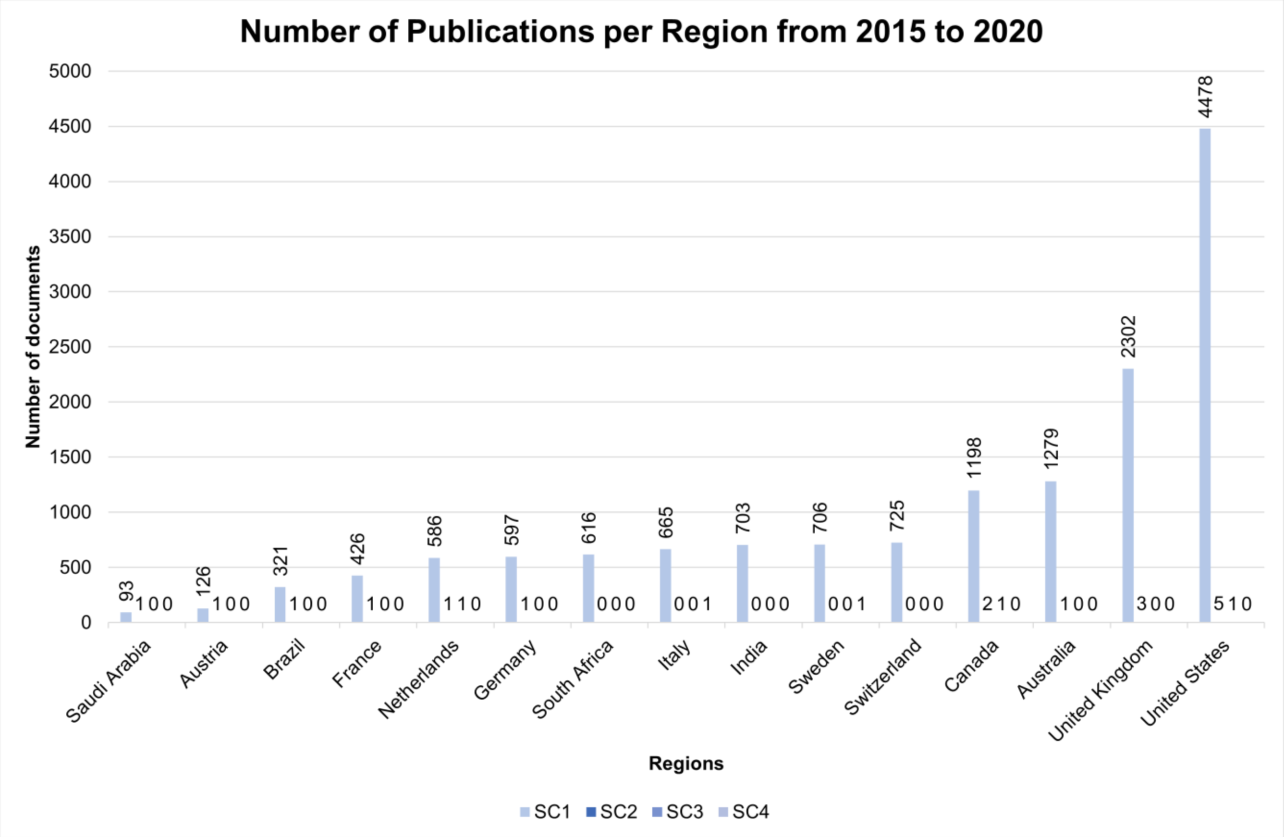


Figure 12: Common regions of the published documents

SC1 is the search combination with the most published articles. However, SC2, SC3, and SC4 have very low numbers of published articles. The data presented in Figure 12 relays the vital information that there is a gap in research about SC2, SC3, and SC4 in certain regions, thus motivating the need for this research. This section assesses the literature on the intersections between healthcare, sustainability (or sustainable development) and sustainable transitions, socio-technical systems, and transitions.

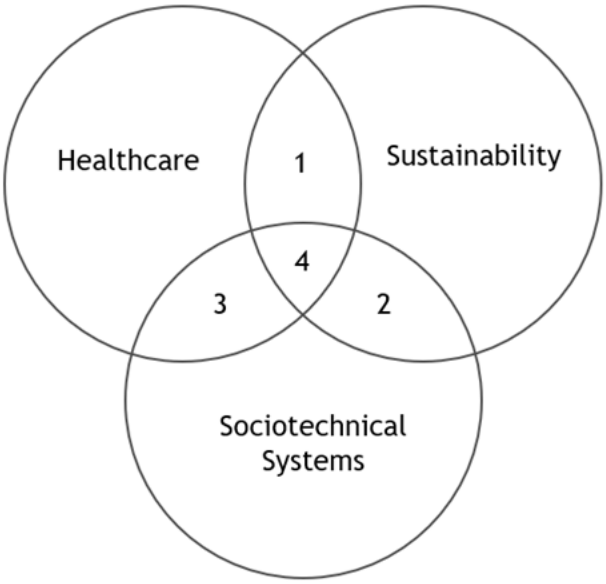


Figure 13: Intersections of literature to be assessed

Intersection 1 in Figure 13 represents search combination 1 (SC1). Intersection 4 aligns with search combinations 2, 3, and 4 (SC2, SC3, and SC4).

The difference between SC2 and SC3, as illustrated in Table 3, is that SC3 focuses on sustainability transitions, which is a pivotal aspect of this research. The search combination, SC4, is concentrated around the main aim of this section, which is to discover the extent to which socio-technical transitions have been incorporated into healthcare.

The categories included are healthcare and sustainability (or sustainable development), which is why no further assessment will be done on intersections 2 and 3. The focus of this section will be based on intersection 4 (SC3 and SC4), but research will also be done on the other intersections to determine the direct and indirect relationships between all three focus areas. Table 5 below depicts the available documents on SC3 and SC4.

Table 5: Data of cited documents in SCOPUS search

# Key term Search Combination	Title	Author	Year	Document Type	Citation Count
SC3	Human Factors Engineering: Status, Interventions, Future Directions in Pediatrics	Ponnala, S., Rivera, A.J.	2019	Review	0
SC3	Cities and sustainable technology transitions: Leadership, innovation, and adoption	Van Geenhuizen, M., Holbrook, J.A., Taheri, M.	2018	Book	1
SC3	Designed to travel? Transition management encounters environmental and innovation policy histories in Finland	Heiskanen, E., Kivisaari, S., Lovio, R., Mickwitz, P.	2009	Article	49
SC4	A multi-stakeholder perspective on sustainable healthcare: From 2030 onwards	Pereno, A., Eriksson, D.	2020	Article	4

The first document, “*Human Factors Engineering: Status, Interventions, Future Directions in Paediatrics*”, conducts a systematic review of the extent to which Human Factors Engineering (HFE) has identified socio-technical systems barriers. This section investigates how socio-technical systems barriers can be mitigated regarding patients, employee safety, and healthcare quality. It also discusses the status of HFE in healthcare and how the science of HFE can further be applied to improve the safety of healthcare delivery processes. Several findings are extracted from this literature. Namely, the HFE has been applied in various healthcare areas in the last few years, including electronic health record (EHR) design, imaging, medication management, patient experience, and care transitions. The HFE interventions include the combination of physical, cognitive, and macro ergonomic principles used to improve healthcare delivery for paediatric patients (Ponnala & Rivera, 2019).

The book, “*Cities and sustainable technology transitions: Leadership, innovation, and adoption*”, discusses the leadership challenges currently evident within emerging transitions towards increased levels of sustainability in various cities. An analysis of elements of three socio-technical systems, energy, transport, and healthcare is presented. The analysis is conducted while simultaneously addressing technological inventions, commercialisation, mass production, and adoption (Van Geenhuizen *et al*., 2018).

The first article about SC3, "*Designed to travel? Transition management encounters environmental and innovation policy histories in Finland*", discusses the new term transition management (TM). Transition management is regarded as a long-term policy design for reflexive governance of socio-technical systems. This article's main aim is to explore the experiences of transferring the TM model into the Finnish context based on two case studies in different sectors (Heiskanen *et al*., 2009).

The final article about SC4, "*A multi-stakeholder perspective on sustainable healthcare: From 2030 onwards*", addresses the possible futures of sustainable healthcare through a collaborating foresight process. This article mentions that sustainable healthcare has been a term growing in popularity, and the transition towards environmental, social, and economic viable health systems is identified as being inevitable and extremely necessary. The outcomes are highlighted in three different areas, namely, environmental, social, and economic, and the drivers that reform the roles of the individual stakeholders, enhancing socio-technical transitions towards the desired scenario that is based on the collaboration between dynamic networks (Pereno & Eriksson, 2020).

The conclusion is made that there is a gap in research about socio-technical transitions in healthcare. There is, therefore, an opportunity for research to be done that jointly analyses the fields of sustainability and sustainable transitions, healthcare, and socio-technical systems. There is a lack of comprehensive literature in regions outside the United States and to some extent, the United Kingdom. The shortage of comprehensive literature in other regions indicates an opportunity for further research. Further research could contribute to the understanding, assessment, and implications of these concepts within other regions as well as contribute to the shortage of literature currently available about these concepts. As the research on these specific concepts becomes more relevant, it could be expected that future researchers and authors will become more distinguished in this field.

In conclusion, this section highlights the need for expanding knowledge within the combination of the specific fields of sustainability, which includes the focus on the transitions to sustainable healthcare systems, healthcare, and socio-technical systems. Further analysis and synthesis of existing literature in these fields are supported by these findings, which identify knowledge gaps to ensure relevant, meaningful, and applicable research outcomes.

3.2 HEALTHCARE AND LEAN THINKING

Literature about lean implementation in healthcare is widely available due to the popularity of lean implementation to improve processes, create value and eliminate waste. Like sustainability in healthcare, the implementation of lean in healthcare has become increasingly popular over the past two decades (De Souza, 2009). Implementing lean thinking in healthcare assists in improving the quality of care that patients receive while increasing the organisation's overall efficiency (Joosten *et al*., 2009; Holden, 2010). Adopting lean thinking into daily operations is challenging, especially considering that lean can only be implemented to a certain extent and is limited to certain parts of an organisation (De Souza, 2009). Thus, a system-wide improvement cannot be expected, but improvements in smaller departments within the system are more feasible (Burgess & Radnor, 2013; Radnor *et al*., 2011).

The adoption rate of lean in healthcare appears to be slower than expected, and it comes with many challenges relating to proper lean implementation, the level of sustainability of the operations, and the level of staff engagement in the infinite cycles of continuous improvement toward "perfection" (Elshennawy *et al*., 2012). Lean is implemented to aid in controlling the operational expenses in the healthcare industry that assist in achieving goals. These goals include a decrease in process defects, a reduction in process cycle times, a decrease in waste, an increase in productivity, and an increase in resource utilisation (Elshennawy *et al*., 2012). The key aspect that causes lean to be more adaptable in healthcare operations than other improvement strategies is the empowerment of staff and the core concept of consistent, continuous improvement, which is essential to the lean theory (De Souza, 2009).

Guimarães and De Carvalho (2014) identified and developed guidelines for healthcare organisations to follow when pursuing lean. This guideline uses the classification of De Souza (2009), as illustrated in Figure 14. It was found that constant monitoring of the improvement process, ensuring that lean practices are in a continuous flow of implementation, and the generalisation of the lean mindset, are the factors that move an organisation into a superior level of lean implementation.

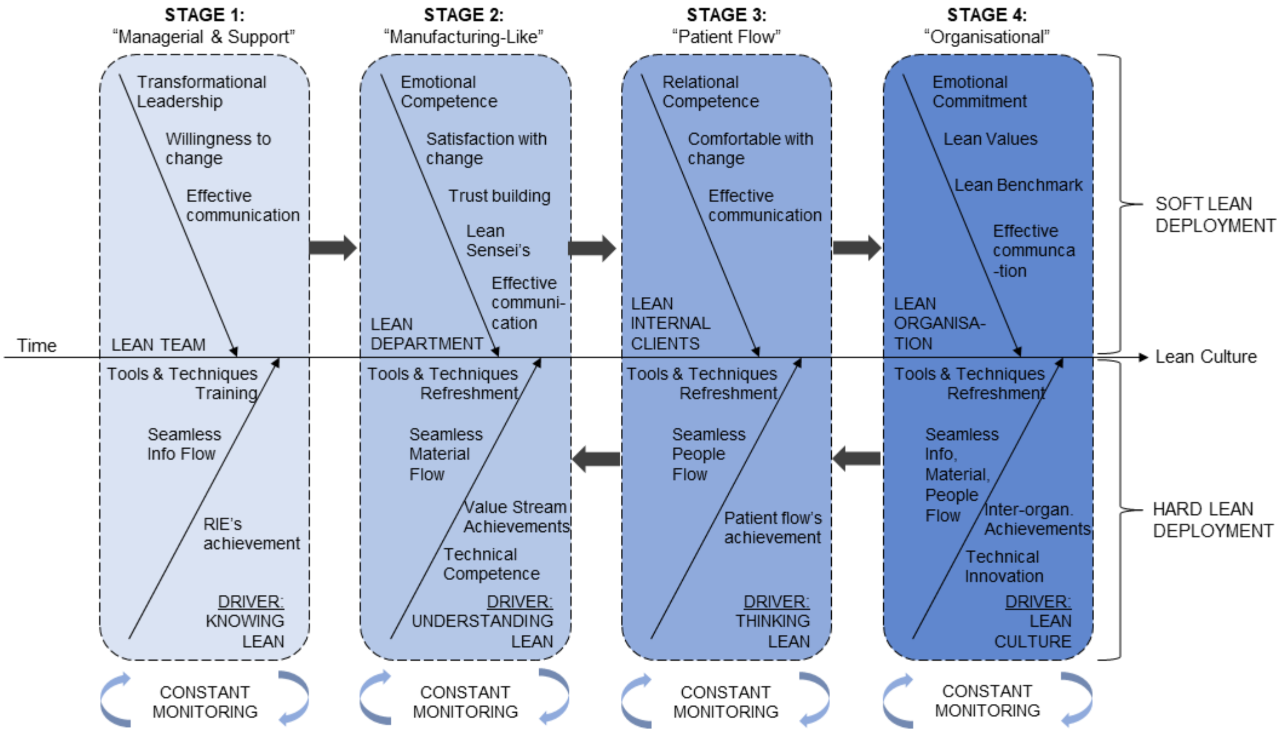


Figure 14: Model of lean maturity in healthcare organisations (Guimarães & De Carvalho, 2014)

The healthcare industry has been evolving in a lean journey by changing behaviours to change thinking, not the other way around (Ahlstrom, 2004). The 4-stage model, as illustrated in Figure 14, includes soft and hard lean deployment dimensions with constant loops between phases, as lean implementation is a continuous cycle. This tool is used as an "as-is" diagnosis method, assessing whether each process step should be improved, disrupted, or discontinued while also providing control measures and possible correctional actions. This model aids in guiding and monitoring the promotion of lean thinking on an individual and organisational level while simultaneously consisting of top-down and bottom-up assessments. Due to the dynamic state of lean deployment, each milestone in the lean journey should be seen as a reference and a starting point for the next milestone. It is common that attempts at lean changes lack constant monitoring and continuous double-loop (re)learning. The lack of monitoring and relearning leads to the inevitable return to the comfort zone, and as a result, lean sustainability is absent (Guimarães & De Carvalho, 2014). The currently available body of literature is limited in supplying an objective quantitative method that measures the level of leanness that adequately addresses the issue of lean sustainability (Wong *et al*., 2014). The basic building blocks of lean methods in healthcare take the form of the house as used by the TPS, which is illustrated in Figure 15.

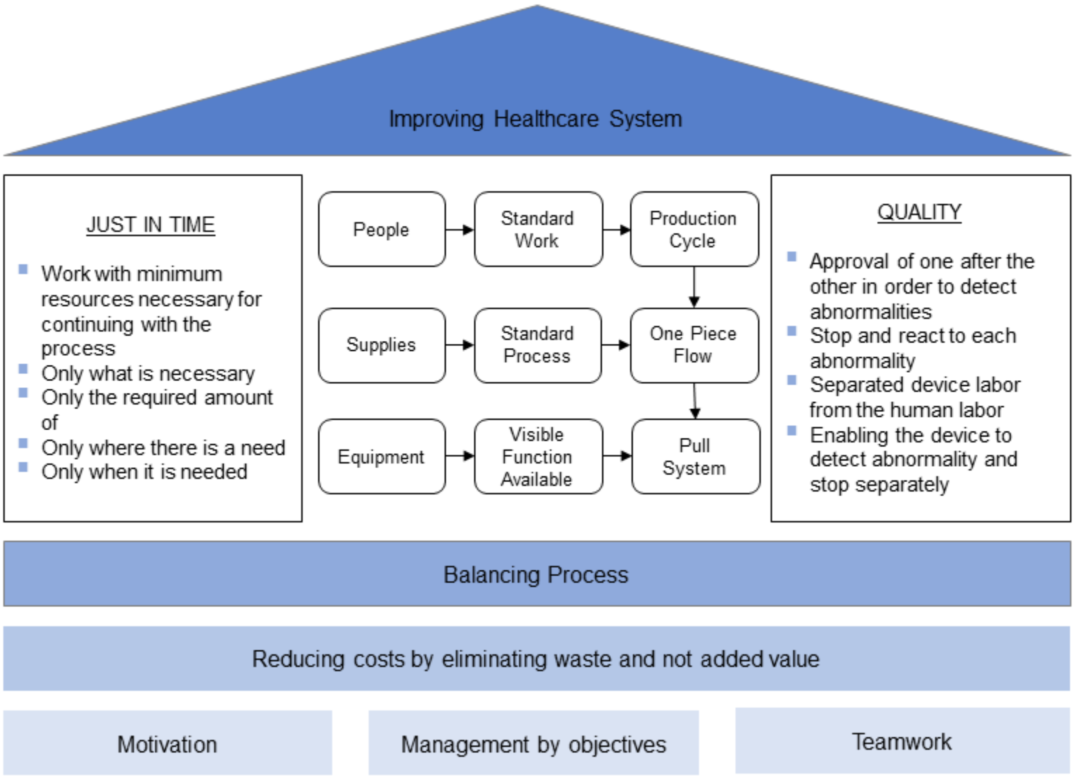


Figure 15: Improving healthcare system (ESCARE, 2013)

The lean philosophy's core concept is implementing continuous improvement by removing non-value-adding activities. The Georgia Institute of Technology found that 40% of healthcare costs are incurred without added value. These non-value-adding steps or activities include time, supply, material, medication, information, and diet. Other predominant non-value-adding activities in healthcare include unnecessary operations or procedures, incorrect administering of medication, time delays of treatments, misdiagnosis, failure to comply with good practice, concealing problems or system errors, and lack of communication. Such non-value-adding activities can lead to disorder, long waiting times, frequent equipment repairs, the inaccurate distribution of materials and tools, a poorly organised workplace and processes, high levels of energy loss, extensive inventories, and the oversight of the expiration of drugs and medical supplies (Demecko & Martinovsky, 2016).

Lean in healthcare systems is about value creation and reducing the burdens patients and healthcare professionals experience. Lean in healthcare focuses on sustaining high levels of quality, safety, satisfaction, and morale within the industry. This is done by aligning the entire workforce around a management system that is consistent and utilising the system to promote, evaluate and implement improvements in processes regularly. Cost-cutting is not the focus of lean management and implementation in healthcare systems. However, it is often the outcome of redesigning activities and workflow to improve the level of care provided. The redesigning of activities and workflow results in saving time and other resources, including benefits such as empowering workers, increasing their engagement, and reducing their sources before burnout occurs (Virginia Mason Institute, 2021).

3.2.1 FIVE KEY PRINCIPLES FOR LEAN IMPLEMENTATION IN HEALTHCARE

Lean implementation in healthcare has five fundamental principles, as illustrated in Figure 16.

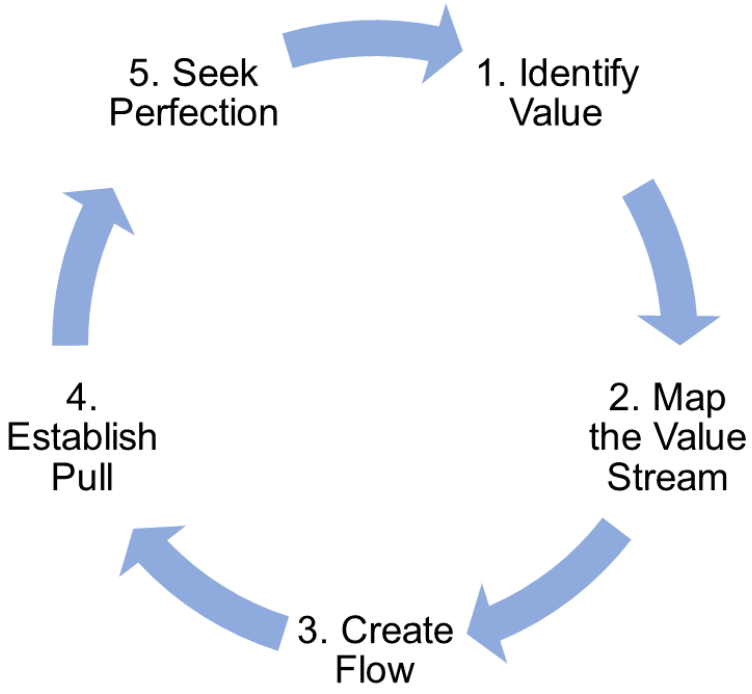


Figure 16: Five key principles for lean implementation (Lean Enterprise Institute (LEI), 2022)

1. *Value* is defined from a customer's perspective and their need for a specific product.

2. *Value stream* entails identifying the end goal (value) and then mapping the steps of the value stream. The steps and processes involved in processing raw materials and delivering the product to the customer. Value Stream Mapping (VSM) or Process Re-engineering is a stepwise analysis where all actions during a process are identified. The idea behind VSM is to map the flow of production, and the aim is to identify each step that does not add value to the end goal and eliminate those identified steps.

3. *Flow* is defined as the non-value-adding activities that have been removed. The next step is to ensure that all the remaining steps in the process flow without disruptions, delays, or bottlenecks. According to LEI (2022), it is beneficial to ensure that value-creating steps in a process occur in a tight sequence to ensure that the product or service flows smoothly to the customer.

4. *Pull* is the process flow, improvement, and the improvement of time to market. Improved process flow and time to market ease delivering products as they are needed (Just in Time). This implies that the customer "pulls" the product as it is needed. The "pull" strategy ensures that excess goods are not manufactured in advance. Products manufactured just in time reduce the number of products to be stored, saving on expensive inventory costs.

5. *Perfection,* defined *as* the most crucial step in lean implementation, ensures that lean thinking and continuous improvement are part of the organisation's culture. It is important to note that lean is not a static system but requires constant effort and awareness to perfect. All employees should be involved in the process of lean implementation (Lean Enterprise Institute (LEI), 2022).

3.2.2 LEAN IMPLEMENTATION ACTIVITIES IN HEALTHCARE

At a very high level, a lean healthcare organisation can be defined by a few activities and principles (Virginia Mason Institute, 2021):

1. *Implementing processes that add value from the patient perspective and eliminate or improve those that do not*

Patient outcomes and experiences define success in healthcare. Possible hindrances in obtaining patient satisfaction include waiting for a service, providers, and answers, travelling across facilities to find ancillary services, and filling out paperwork in person instead of online ahead of time. Improving or eliminating these challenges does not cut costs, but it contains other benefits that contribute to the patients' experience.

2. *Aligning leaders and staff around a shared vision*

Lean management deploys the entire workforce to improve the work and tasks that matter the most to the organisation. Clear goals are set by leaders, while the teams and individuals adopt their own goals to support the organisation's goals. This alignment drives results for the organisation's priorities and improves the general satisfaction and engagement of staff by including them in vital and valued discussions and decisions.

3. *Promote a culture of continuous improvement*

Maintaining high levels of quality and service is a continuous process. Lean healthcare organisations provide a structure and culture for the workers to sustain quality and safety during everyday tasks.

4. *Empowering frontline staff to drive improvement efforts*

Frontline workers who drive continuous improvement increase the possibility of the implementation becoming more successful. Leaders in healthcare show respect for the lean implementation by stepping back from the role of "problem-solver" and instead taking on the general role of "problem-framer". Healthcare leaders taking on the role of "problem-framer" are active at the place where the frontline workers deliver care to patients. They would monitor the actions of the frontline workers, ascertain the frontline worker's motivation for actions, and empower frontline workers and other team members to initiate and drive improvement. The key role of "problem-framers" is to give frontline workers the opportunity and tools to identify inefficiencies within their departments and implement adapted or new, more effective methods.

5. *Finding the root cause of pain points and inefficiencies*

Continuous improvement in healthcare can be implemented by using root cause analysis to determine the true source of each problem. Root causes of problems can often lead to unnecessary or harmful outcomes if not identified and rectified early in the process.

6. *Flexibility and willingness to change*

With patient care being a dynamic process, lean organisations implement solutions that result in operations being carried out differently than initially planned or intended. The willingness to attempt new solutions to problems is more important than the impulse to improve. When quality improvement, strategic alignment, empowerment of staff and frontline workers, and other competencies are engraved into the core of the daily operations, lean organisations have all the required tools and mindsets to "iterate, flex, evolve and innovate".

3.3 HEALTHCARE AND SUSTAINABILITY TRANSITIONS

Limited research has been conducted on the appearance of sustainability transitions in healthcare. Different definitions of sustainable healthcare systems exist. Regardless of whether the three-pillar model or the integrated understanding of sustainability is applied, all approaches implicate a comprehensive approach with a long-term focus and a need to balance economic, social, and ecological interests (Pereno & Eriksson, 2020). Economic sustainability is a pivotal factor that could lead to budget cuts which affect the quality of the services provided by healthcare. Economic sustainability encourages qualitative views for saving from the point of view of reduction and optimisation of resources, processes, and supplies (Clemens *et al*., 2014; Evans *et al*., 2017). Economic sustainability demands higher efficiency and sustainability. Healthcare stakeholders should aim to decrease environmental impacts and prevent environmental diseases. Therefore, it is important that healthcare stakeholders re-evaluate their contribution toward environmental aspects (Sherman & Ryan, 2010). Sustainable healthcare is becoming a core responsibility in local and international policies, increasing healthcare systems' sustainability. European healthcare systems are faced with challenges that include high healthcare costs and economic pressures to ensure universal coverage and equitable access and financing (Thomson *et al*., 2009). The increasing cost and economic pressure give rise to the fact that European healthcare focuses on sustainable healthcare within the economic paradigm. This initialises the new concept of resilient healthcare systems that responds to contemporary challenges and ensures high-quality healthcare is part of the future (European Steering Group on Sustainable Healthcare, 2015).

Environmental sustainability aims to reduce energy and water consumption and decrease waste while eliminating associated costs. Environmental sustainability results in a financial return on investment. Other initiatives making headway in healthcare systems are obtaining non-toxic chemicals, medical appliances and devices utilising fewer chemicals, and healthier foods. The initiatives add to the positive outcome of a patient’s health (Sutter, 2012). Awareness of sustainability is growing in healthcare systems. The main challenge experienced by healthcare organisations is how to manage the large variety of efforts supporting environmental sustainability while incorporating them into clinical operations more effectively (Boone, 2012).

Sustainable healthcare systems are a growing subject in research and policy trends, but the transition toward sustainable healthcare seems to entail complex issues that bring about many challenges. A paradox is evident as there is a need to acquire new knowledge and skills regarding sustainability. However, creating a dialogue between the various disciplines and sectors is challenging. These disciplines are pivotal in creating a new mindset in professional healthcare. Healthcare should be designed for the people, the practitioners, and society while promoting an astute approach to healthcare systems to tackle their economic, social, and environmental issues (Jones, 2013). The complexity of sustainable healthcare highlights the aim for healthcare systems to integrate sustainability goals into their proposition, creation, and value capture. However, the transition of socio-technical systems requires a holistic approach that manages the multi-level and stakeholder complexity (Boons & Lüdeke-Freund, 2013).

A substantial body of literature has focused on developing sustainable healthcare systems. However, healthcare systems still experience significant challenges in terms of the economic, social, and environmental challenges that persistently occur in healthcare systems and organisations globally. Sustainability is becoming an increasingly popular concept because organisations are becoming more aware of the need to understand and acknowledge resource scarcity (University of Alberts, 2016). This movement approach is a holistic approach where economic, social, and environmental factors are considered simultaneously to “bring forward existing prosperity” (Kates *et al*., 2005).

Sustainable healthcare is the access point to providing higher quality healthcare at lower costs, but cost efficiency and the effectiveness of healthcare cannot be achieved concurrently (Karamat *et al*., 2019). The effectiveness of the healthcare system is indicative of the system's ability to achieve the maximum possible outcome. It has been proven that there is an apparent compromise between the increase in effectiveness and efficiency (lo Storto & Goncharuk, 2017). Healthcare is often intertwined with ethical implications regarding human well-being. From a societal perspective, the intertwined nature of healthcare underlines the importance of developing sustainable healthcare services (Marjanovic *et al*., 2020).

According to WHO (2012), "*a well-functioning healthcare system requires a robust financing mechanism; a well-trained and adequately-paid workforce; reliable information on which to base decisions and policies; well-maintained facilities and logistics to deliver quality services*". To become a well-functioning healthcare system, sustainability in healthcare should be considered from all perspectives.

3.3.1 HEALTHCARE BUSINESS MODEL INNOVATIONS FOR SUSTAINABILITY TRANSITION

The structuring of health systems as an organisation of specialised healthcare took place in the early 20th century. The health system underwent transitions, but only on a natural and incremental improvement basis. Healthcare systems are complex organisations due to the different interactions between the actors within the system. Actors within the healthcare system include suppliers, legal regulators, medical health plans, and patients. The individual needs of the different actors have consequences for the healthcare business model, especially for the development of sustainability within the system. Multi-level perspective (MLP) is introduced within the healthcare context while providing an analysis of "how the transition process is not linear" (Geels, 2002).

The interactions between the various actors are generated between three analytical levels. The three analytical levels are *niches* (locus of business model), *regimes* (the locus of established practices and rules that stabilise the existing systems through innovation), and *landscapes* (external socio-economic situation) (Geels, 2002). The *landscape* has an increased level of stability in comparison to the lowest-level actors and the degree of alignment within the elements (Lopes *et al*., 2018). To reach the multi-level *landscape*, the business model of each actor within the healthcare chain must be structured. The multi-level *niches* must be supported by structured strategies and other technological, service, organisational, social, and cultural multi-level *regimes,* which extend to the multi-level *landscape*. The multi-level landscape aims to generate activities for the actors through business partnerships, governance, and social responsibility, which generates social actions, and ecological and sustainability services. As these actions at the multi-level mature, a sustainability transition becomes achievable. Business models driven by innovation will allow healthcare systems to create sustainability transitions that support the increase in demand while guaranteeing the needs of future generations. Exploring options and concepts relating to the business models for innovations in healthcare systems is pivotal to ensuring an improved possibility of success in a sustainability transition. Innovation in healthcare creates opportunities for cost reduction, environmental impact monitoring, quality improvement, strategic gains, legal requirement fulfilment, process efficiency, and new technology introduction (Hekkert & Negro, 2009). The healthcare model for sustainability transition should include business models which promote sustainability while considering other issues of new technologies, practices, and management (Lopes *et al*., 2018).

The implementation of the model requires that the healthcare chain is idealised.

1. Generate *awareness* of the need for actions to change towards increased sustainability;

2. Create a *culture* of sustainable business models (SBMs) which stimulates the chain towards increased sustainability;
3. Manage *new initiatives*, distribute information on ongoing actions, and keep people informed;
4. Manage *innovations* by developing methods to manage ideas and innovations of the chain. It can be treated as a systematic method, which encompasses the strategy, resources, organisational models, processes, and tools which are geared towards the generation of an organisational culture where innovation is supported; and
5. Involve *external actors* by encouraging the participation of industries, actions, and other forms of support.

3.3.2 INTERRELATEDNESS OF SUSTAINABILITY TRANSITIONS AND SUSTAINABLE BUSINESS MODEL

Sustainability transformation can be defined as a "long-term, multi-dimensional, and fundamental transformation process that establishes socio-technical system shifts to more sustainable states of production and consumption" (Köhler *et al*., 2019). The debate regarding sustainability transitions has raised multidisciplinary issues and complex problems, highlighting various possible solutions. One possible solution getting much attention is transforming a production-consumption system into a circular model where the output from one sub-system is the input for another sub-system (Potting *et al*., 2017). This CE optimises resources that contribute to maintaining the balance between the economic, social, and environmental impacts. At the same time, CE is a facilitator in creating efficient and regenerative resources through optimisation (Urbinati *et al*., 2017; Winans *et al*., 2017). CE involves using fewer resources, prolonging the use of resources, reusing the resources, and improving the natural environment of resource loops (Bocken *et al*., 2016). CE is a model presentation of an idealistic solution to the global challenges of resource scarcity and environmental damages while attempting to establish an economic system that incorporates feedback loops (Nadeem *et al*., 2017; Van Loon & Van Wassenhove, 2020). Researchers have proven that the concepts of CE have great potential to benefit users. However, a significant factor contributing to the ineffective use of CE is the lack of an in-depth understanding of the implementation stage and what it entails (Chay *et al*., 2015), even with resource investments (Garza-Reyes, 2015). CE has promoted novel and radical reuse and recycling technologies, as well as the development of innovative business models which contributes to sustainability transitions (e.g., the Sustainability Business Model (SBM) creates value from waste or delivers functionalities (González-Sánchez *et al*., 2020)). Similarities and differences between SBM and sustainability transitions are illustrated in Table 6.

Table 6: Similarities and differences between SBM and sustainability transitions (adapted from (Lopez *et al*., 2018; Bocken *et al*., 2016)

	SBM	**Sustainability Transition**
Concept	It creates significant positive results and reduces negative impacts on the environment and society by changing the way the company and its network create, deliver, and capture value or change its value proposition.	Long-term, multi-dimensional, and fundamental transformation processes established socio-technical transitions to more sustainable states of production and consumption.
Key Issues	Innovation is the driver which improves business, society, and the environment. Positive impact on internal and external organisational structures The sustainable vision of organisations and stakeholders	Innovation promotes sustainability transitions. Positive impact on societies and industries The sustainable vision of organisations, societal actors, and stakeholders

	SBM	Sustainability Transition
Scope	Internal and external organisational structures	Societies and industries
Focus	To operate a business with positive impacts on society, the natural environment, and the business.	To solve societal challenges and needs through sustainable production and consumption.
Dimension	Micro	Micro, meso, and macro

3.4 SUSTAINABILITY TRANSITIONS AND LEAN THINKING

Literature regarding the integration of lean thinking and sustainability transitions is limited since these concepts are misaligned. However, the interrelatedness of lean thinking and sustainability transition characteristics are used to identify whether the incorporation of lean into sustainability transitions is supported. The interrelatedness of lean thinking and sustainability transition proposes a holistic approach to solving the current universal challenges of resource scarcity and environmental impacts.

3.4.1 LEAN PRINCIPLES

According to research, there are 12 basic lean principles. These lean principles are illustrated in Table 7 below.

Table 7: The 12 lean thinking principles (Tăucean *et al*., 2018)

No.	Lean's principle
L1	Reducing/Eliminating activities that do not add value
L2	Reducing uncertainty
L3	Focus on customer requirements
L4	Reduce cycle time
L5	Simplifying the process
L6	Increase production flexibility
L7	Increase process transparency
L8	Controlling the entire process
L9	Improving the process continuously
L10	Gathering information about competitors
L11	Reduction of raw materials
L12	Efficient allocation of human resources

Taiichi Ohno (1988) developed a concept of lean management that consists of aspects such as identifying value, value stream mapping, continuous flow creation, establishing a pull system, and seeking perfection (Mourtzis *et al*., 2016). These principles focus on simultaneous waste elimination and value creation (Womack *et al*., 2007). The sequential flow of the principles is described below:

i. Identifying value as viewed from the perspective of the customer (Pampanelli *et al*., 2014);
ii. According to the previously defined definition of value, identify and conduct value stream mapping (Pampanelli *et al*., 2014; Mostafa *et al*., 2013);
iii. Ensure the smooth creation of information, material, and other resources flow while creating value (Seth *et al*., 2017);
iv. Eliminate overproduction and excess inventory by establishing a pull system where production is dependent on customer demand (Sundar *et al*., 2014); and

v. Seeking perfection by implementing strategies to ensure a culture of continuous improvement while continuously eliminating non-value-adding activities and other occurrences of waste (Pampanelli *et al*., 2014; Vlachos, 2015).

3.4.2 SUSTAINABILITY TRANSITION CHARACTERISTICS & PRINCIPLES

Essential characteristics are highlighted to differentiate sustainability transitions from historical transitions. The differences between sustainability and historical transitions are:

i. Sustainability transitions are aimed toward a sustainable future to assist in solving societal challenges (Smith *et al*., 2005). This has not necessarily been the goal of historical transitions, where the main aim was to explore new ideas and opportunities that could potentially lead to economic growth;

ii. Transitions toward sustainable socio-technical systems could require that changes need to be made to the economic frameworks; and

iii. Firms, technologies, and other providers need to use complementary assets, such as manufacturing, supply chain, and technologies, which will increase the implementation of sustainable solutions. These "complementary assets" that support sustainability can assist in the breakthrough of sustainable innovations (Geels, 2011).

The United Nations proposed 12 sustainability principles that address sustainability at an enterprise level. The sustainability principles are illustrated in Table 8.

Table 8: The 12 sustainability principles, the implications, and SDGs of Agenda 2030 (United Nations, 2022)

No.	Sustainability's Principle	Implication	SDG
S1	Reduce resources	Reducing process losses contributes to improving financial results.	9 Industry, Innovation and Infrastructure; 12 Responsible Consumption and Production
S2	Time efficiency	Improving the time of the operational processes contributes to increased production capacity and reduced cost.	9 Industry, Innovation and Infrastructure; 12 Responsible Consumption and Production
S3	Reduce waiting time	The reduction in waiting time improves the production capacity.	9 Industry, Innovation and Infrastructure; 12 Responsible Consumption and Production
S4	Monitor fixed cost	Reducing energy consumption improves the financial results and reduces environmental impacts.	12 Responsible Consumption and Production; 17 Partnerships for the Goals
S5	Stakeholder involvement in strategic decisions	Strategic decisions need to be agreed upon by stakeholders to increase attractiveness and efficiency (involving stakeholders from within).	6 Clean Water and Sanitation; 8 Decent Work and Economic Growth; 17 Partnerships for the Goals
S6	Support community activities	The company must meet the communities' needs, which can contribute to an improved level of competitiveness.	2 Zero Hunger; 3 Good Health and Well-Being; 16 Peace, Justice and Strong Institutions
S7	Train human resources	Continuous training of human resources improves the company's performance level.	4 Quality Education; 5 Gender Equality
S8	Corporate Social Responsibility (CSR)	The company's level of involvement in CSR can improve attractiveness and competitiveness.	1 No Poverty; 10 Reduced Inequalities

No.	Sustainability's Principle	Implication	SDG
S9	Increase recycling capacity	The company must be able to recycle the waste generated to reduce the environmental impact.	14 LIFE BELOW WATER; 15 LIFE ON LAND
S10	Increase capacity of reuse, remanufacture, and recondition	Process-generated waste must be informed of other processes to reduce the amount of waste generated.	7 AFFORDABLE AND CLEAN ENERGY; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION
S11	Reduce energy consumption	Improving the operational processes of a company reduces energy consumption. Companies are required to increase their capacity to generate energy.	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 13 CLIMATE ACTION
S12	Reduce Greenhouse gas emissions	Reducing pollution to the environment.	11 SUSTAINABLE CITIES AND COMMUNITIES; 13 CLIMATE ACTION

3.4.3 INTERRELATEDNESS OF LEAN AND SUSTAINABILITY

Lean and sustainability transitions have different methods of reaching their shared goals of "waste elimination" and "value creation", as illustrated in Table 9 below.

Table 9: Waste and value of lean and sustainability transitions

	Lean	Sustainability Transition
Waste	Waste is defined as a non-value-adding activity as perceived by the customer (Campos & Vazquez-Brust, 2016). "Anything other than the minimum amount of equipment, materials, parts, space, and time which are essential to add value to the product" (Russell & Taylor III, 2011). Waste is classified as transport, inventory, movement, waiting, overproduction, overprocessing, and defects (Ohno, 1988). An additional waste identified by western industries during the 1990s is the underutilisation of worker talent and skills (Triagus *et al*., 2013).	"Waste can be both generated from a resource or an environmental problem" (Sustainable Development Goals, 2011). The wastage of usable (thus valuable) resources It is identified as wasted resources, lifecycles, capabilities, and embedded values (Lacy & Rutqvist, 2015).
Value	Value is viewed as perceived by the customer (Martínez León & Calvo-Amodio, 2017). By identifying customer requirements, the perceived idea of value is determined (Hines *et al*., 2004).	Waste can be reduced by recycling waste (van Buren *et al*., 2016; United Nations, 2011) . Producing as little waste as possible. Where waste must be produced, the aim should be that it is as non-hazardous as possible (Sustainable Development Goals, 2011).

As described in Table 9, it is evident that lean and sustainability transitions have common elements and goals which support the interrelatedness between the two concepts. Incorporating lean thinking into sustainability transitions can enhance value creation by efficiently using resources. The efficient use of resources can lead to cost reduction and increased revenue generation. Waste elimination using only the required types and amounts of resources is crucial for the efficient use of resources. Lean principle implementation increases competitiveness and improves production efficiency

(Cherrafi *et al*., 2017; Ruben & Asokan, 2017). According to Cherrafi (2017), sustainable development is essential during any lean approach. It reduces energy consumption and environmental pollution and streamlines material consumption, which covers sustainability principles (Cherrafi *et al*., 2017). Table 10 illustrates the interaction, similarities, and complementarities between the 12 Sustainability Principles and the 12 Lean Principles (Tăucean *et al*., 2018; United Nations, 2022).

Table 10: Interaction matrix between lean and sustainability (adapted from Tăucean *et al*., 2018; United Nations, 2022)

Sustainability's Principle	**Lean's Principle**												**Similarities**	**Complementarity**	**SDG**
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12			
S1	x	x		x			x		x		x	x	Reducing resources	Lean responds punctually to different resources.	SDG 9 SDG 12
S2		x	x				x						Time efficiency	Lean streamlines operations; sustainability plans.	SDG 9 SDG 12
S3			x		x								Waiting time	Lean gets the product in a short time; sustainability reduces the time allotted.	SDG 9 SDG 12
S4									x		x		Process costs	Lean gets the product in a short time; sustainability reduces the time allotted.	SDG 12 SDG 17
S5										x		x	Stakeholder interest	Lean evaluates competitors' operations and allocates efficient human resources; sustainability involves stakeholders in decision-making.	SDG 6 SDG 8 SDG 17
S6			x									x	Activities for people	Lean involves employees; sustainability supports the organisation's involvement in society.	SDG 2 SDG 3 SDG 16
S7								x				x	Human resources	Lean pursues resource efficiency; sustainability supports employee training.	SDG 4 SDG 5
S8												x	CSR	Lean sustains organisational efficiency; sustainability activities for society.	SDG 1 SDG 10
S9					x	x			x				Recycling	Lean aims to reduce losses; sustainability aims to increase the recycling rate.	SDG 14 SDG 15

Sustainability's Principle	Lean's Principle												Similarities	Complementarity	SDG
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12			
S10	x					x		x					Reverse logistics	Lean supports loss reduction; sustainability supports reverse logistics (returning waste to production as raw materials).	SDG 7 SDG 12
S11		x			x	x	x	x	x				Energetic efficiency	Lean reduces loss; sustainability sustains the production of green energy.	SDG 9 SDG 13
S12	x			x	x			x	x		x		Pollution Reduction	Lean reduces waste; sustainability is aimed at reducing greenhouse gases.	SDG 11 SDG 13

3.5 CHAPTER 3: CONCLUSION

This chapter provides an analysis that indicates the gap in knowledge about sustainability transitions in healthcare as a socio-technical transition. Literature about the integration of the three focus areas of this research, being healthcare, sustainability transitions, and lean, was also discussed to determine the level at which these concepts have been researched in combination with each other.

CHAPTER 4: REQUIREMENT SPECIFICATIONS

In this research project, a systems engineering approach is implemented to address the lack of research products where lean thinking is used to support sustainability transitions in healthcare. Chapter 2 and 3, the input identification phase, consists of an in-depth literature analysis that contextualises the research problem. Specific requirement specifications need to be developed to advise on a healthcare system that will effectively address sustainability challenges.

This section, as illustrated in Figure 17, discusses and identifies the requirement specifications that will aid as a guideline in the development phase of the research products. The requirement specifications are presented to fulfil RO2 (refer to Section 1.3).

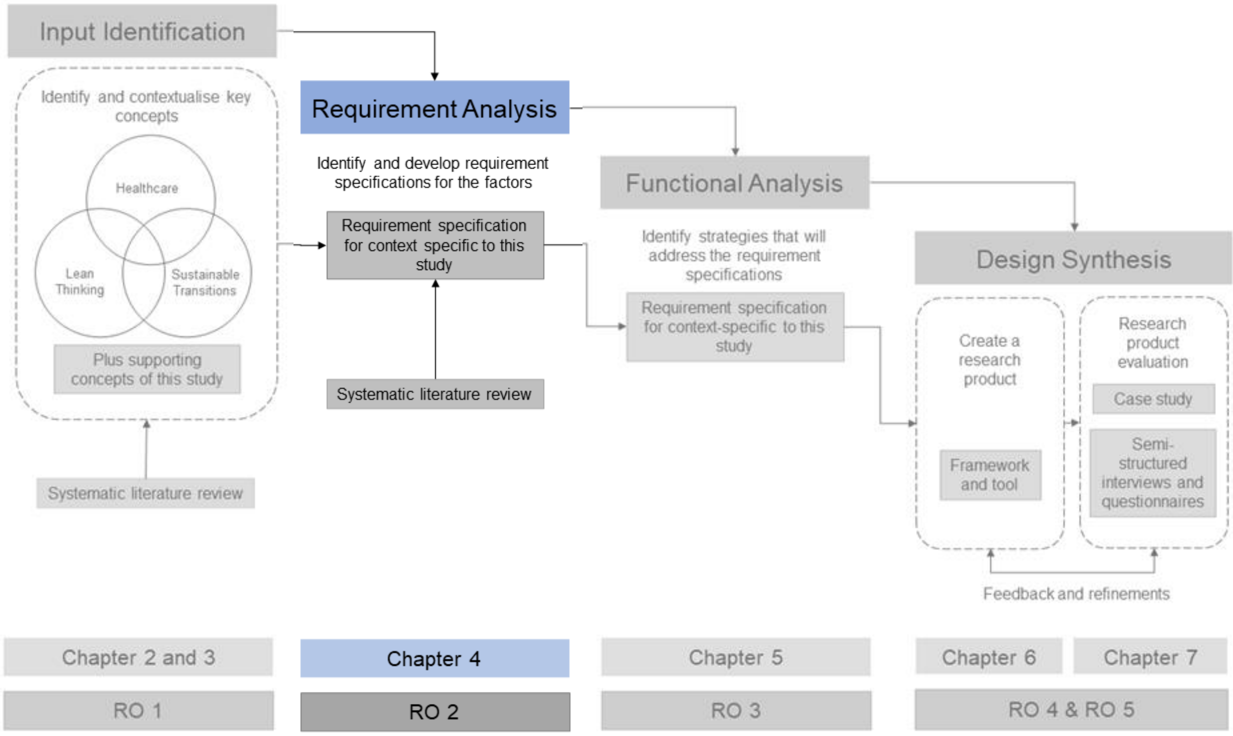


Figure 17: Requirement analysis of adapted systems engineering approach

The development of these requirement specifications is discussed, and the developed set of requirement specifications is identified. This is followed by a discussion on the verification process, which entails identifying whether the developed set of requirement specifications is satisfactory.

4.1 REQUIREMENT SPECIFICATION TYPES

This section provides the necessary guidance and foundational concepts that can be translated into requirement specifications that the research products need to adhere to. A distinction between five requirement types has been made (Van Aken *et al*., 2007).

i. **Functional requirements (FR):** The key driver of the specification which highlights the performance demands to be designed or incorporated;

ii. **User requirements (UR):** The requirements are identified by the user, which explains how the research products are expected to work and thus identifies the required skill requirements to use the research products effectively;

iii. **Design restrictions (DR):** These are requirements that contain the preferred solution space with specific limits and exclusions;

iv. **Attention points (AP):** These are relevant requirements that should be considered during the development process of the research products; and

v. **Boundary conditions (BC):** These are rigid requirements that include legal, health, and safety requirements. These requirements may not be altered and must be met.

4.2 REQUIREMENT SPECIFICATION

This section highlights and discusses the five requirement types utilised during the development phase. The distinct requirements will be identified within each of the five requirement types mentioned and defined in Section 4.1. Aken's (2007) requirement specification types have been used as a guide to identify and develop the requirement specifications.

4.2.1 FUNCTIONAL REQUIREMENTS (FR)

The functional requirements are the specifications of what the developed research products must deliver in terms of performance (Van Aken *et al*., 2007). These specifications stipulate the requirements for the optimal performance of the research products. As previously highlighted in Chapter 3, it is expected that the research products should contribute towards the knowledge gaps and disconnection to contribute positively towards fulfilling the aim of this research, given the findings in the literature. Table 11 below illustrates the requirement specification, the description, the motivation for the requirement specification, and the relevant chapter reference. Functional requirements for the research products are:

i. The research products should sufficiently integrate lean thinking into sustainability transitions in healthcare;

ii. The research products should approach sustainability transitions from a socio-technical transition perspective;

iii. The research products should incorporate an understanding of sustainability transitions in healthcare within a holistic context; and

iv. The research products should apply to societal systems.

Table 11: Functional requirements

Requirement Specification ID	Description	Motivation	Chapter reference
FR1	The research products should sufficiently integrate lean thinking into sustainability transitions in healthcare.	The need for the research products stems from the lack of literature integrating the concepts of lean thinking implementation within sustainability transitions in healthcare. The research products should therefore contribute towards filling this knowledge gap.	Chapter 3
FR2	The research products should approach sustainability transitions from a socio-technical transition perspective.	The need for the research products originates from the lack of literature integrating the concepts of lean principle implementation within sustainability transitions in healthcare. The research products should therefore contribute towards filling this gap.	Chapter 2
FR3	The research products should incorporate an understanding of lean thinking in healthcare within a holistic context.	The need for the research products arises from the lack of literature integrating the concepts of lean thinking implementation within sustainability transitions in healthcare. The research products should therefore contribute towards filling this gap.	Chapter 2

Requirement Specification ID	Description	Motivation	Chapter reference
FR4	The research products should apply to socio-technical systems.	As this research aims to improve sustainability transitions in healthcare systems, the developed research products must be applied to these systems.	Chapter 2

4.2.2 USER REQUIREMENTS (UR)

The user requirements specify certain specifications from the viewpoint of the user. Systems engineering provides guidelines for the development of user requirements. Table 12 below illustrates the requirement specification, the description, the motivation for the requirement specification, and the relevant chapter reference. It is expected that the research products adhere to the following user requirements:

i. The research products should be understandable and unambiguous;
ii. The research products should be clear and concise;
iii. The research products should provide clear definitions and explanations to cater to a broad range of levels of experience in lean, sustainability transitions, and healthcare; and
iv. Practical implementation strategies and utilities should accompany the research products because it is developed from an engineering perspective.

Table 12: User requirements

Requirement Specification ID	Description	Motivation
UR1	The research products should be understandable and unambiguous.	The research products should be easy to follow and understand, especially for users unfamiliar with lean principle implementation into sustainability transitions in healthcare.
UR2	The research products should be clear and concise.	Implementing lean thinking to facilitate and support sustainability transitions in healthcare.
UR3	The research products should provide clear definitions and explanations to cater to a broad range of levels of experience in lean, sustainability transitions, and healthcare.	The research products should be easy to follow and understand, especially for users unfamiliar with lean principle implementation.
UR4	Practical implementation strategies and utilities should accompany the research products because it is developed from an engineering perspective.	The research products are developed from an engineering perspective which requires a practical application to academic products. The framework itself is not developed to address this directly. However, a tool should be presented alongside it to guide users on navigating implications for practical insights drawn from the research products for their respective fields/sectors.

4.2.3 DESIGN RESTRICTIONS (DR)

The design restrictions discuss the preferred solution space for the research products. Socio-technical transitions have been included in the research, but it was mainly conducted from a multi-discipline perspective. Table 13 below illustrates the requirement specification, the description, the motivation for the requirement specification, and the relevant chapter reference. Given that the author conducted the study from an engineering perspective, the research products are expected to have the following design restrictions:

i. The research products are developed from an Industrial Engineering perspective, as it is the discipline of this research. SMEs could add inputs from other disciplines from other fields of research;
ii. The research products do not provide new meaning or theory around lean thinking and sustainability transitions. However, it integrates lean thinking into sustainability transitions in healthcare using theory and examples from literature resources; and
iii. The research products exclusively take on a socio-technical transition perspective towards sustainability transitions.

Table 13: Design restrictions

Requirement Specification ID	Description	Motivation
DR1	The research products are developed from an Industrial Engineering perspective, as it is the discipline of this research. SMEs could add other inputs from other disciplines in specific fields of research.	The research products should gain input from SMEs to ensure that using lean thinking to facilitate and support sustainability transitions is logical and accurate.
DR2	The research products do not provide new meaning or theory around lean thinking and sustainability transitions. However, it integrates lean thinking into sustainability transitions in healthcare using theory and examples from literature resources.	The intent of developing the framework, methodology, and index is not to create new theories and meanings around lean thinking and sustainability transitions in healthcare. The framework, methodology, and index are intended to support sustainability transitions in healthcare through lean implementation. The research products are developed by using systems engineering and industrial engineering principles. It should not be restricted to the industrial engineering field but should be developed to be applicable to other fields.
DR3	The research products exclusively take a socio-technical transition perspective towards sustainability transitions.	Various transition perspectives have been acknowledged, such as socio-economic, socio-ecological, sectoral systems of innovations, and innovation systems. This research focuses on socio-technical transitions, and therefore the research products exclusively take a socio-technical perspective focusing on society and system functions towards the greater sustainability good. Detailed effects on other spheres, such as the environment and economy, may be added in future work on the research products.

4.2.4 ATTENTION POINTS (AP)

The attention points are those requirements that must be addressed during the research products' development. Table 14 below illustrates the requirement specification, the description, the motivation for the requirement specification, and the relevant chapter reference. The attention points for the research products are:

i. The research products should aid as a guide in academic research regarding the key topics of this research, being lean thinking implementation to facilitate and support sustainability transitions in healthcare;
ii. The research products' guidelines and solutions should not exceed the required limit of expectations;

iii. The research products should be used when specific sustainability needs are identified and highlighted; and

iv. The research products may be the approach to developing a deeper understanding of novel sustainability transitions that include lean thinking.

Table 14: Attention points

Requirement Specification ID	Description	Motivation
AP1	The research products should aid as a guide in academic research regarding the key topics of this research, being lean thinking implementation to facilitate and support sustainability transitions in healthcare.	The research products should not deviate from the key topics of this research, as it is essential to ensure that all initial objectives are met.
AP2	The research products' guidelines and solutions should not exceed the required limit of expectations.	The research products should deliver the expected outcomes by using lean thinking to facilitate and support sustainability transitions in healthcare.
AP3	The research products should be used when specific sustainability needs are identified and highlighted.	Depending on the systematic use of the research products, it should contribute towards facilitating and supporting sustainability transitions in healthcare.
AP4	The research products may be the approach to developing a deeper understanding of novel sustainability transitions that include lean thinking.	The research products can contribute to the literature gap about lean principle implementation into sustainability transitions in healthcare.

4.2.5 BOUNDARY CONDITIONS (BC)

The boundary conditions stipulate the restrictions that must be met for the research products to work as initially intended during development. The research products are developed on a high level, discussing the analysis of the integration of lean thinking and sustainability transitions. It, therefore, aims to add support to further research. Table 15 below illustrates the requirement specification, the description, the motivation for the requirement specification, and the relevant chapter reference. Given this premise, the boundary conditions for the research products are:

i. The research products are most appropriate for the application to healthcare systems in the quest to fulfil sustainability targets and overcome challenges experienced in healthcare;

ii. The research products must be utilised by users with some basic prior knowledge of the concepts at hand;

iii. The research products can only be applied with contextual contributions from the users; and

iv. The research products are exploratory in their application and are not to be used as a prescribed method to integrate lean thinking in sustainability transitions in healthcare.

Table 15: Boundary conditions

Requirement Specification ID	Description	Motivation
BC1	The research products are most appropriate for the application to healthcare systems in the quest to fulfil	The research products are developed to explore and understand concepts of using lean thinking to facilitate and support sustainability transitions in healthcare and to understand these relationships. The research products

Requirement Specification ID	Description	Motivation
	sustainability targets and overcome challenges experienced in healthcare.	should, therefore, not be applied as-is to solve any context-specific issues or prescribed as a solution. The author does not claim that the research products are the ultimate research products of using lean thinking to facilitate and support sustainability transitions in healthcare.
BC2	The research products must be utilised by users with some basic prior knowledge of the concepts at hand.	The developed research tools should not decrease the value of any parties involved. As the research products are merely guidelines to facilitate sustainability transitions in healthcare, they should contribute constructively to all who use them.
BC3	The research products can only be applied with contextual contributions from the users.	As understood from the literature, socio-technical transitions, healthcare, and lean thinking are not homogenous in the application. However, different socio-technical transition aspects may have implications that need to be considered. Context may be related to specific societal systems and how they are affected by factors such as geographical location, socio-economic context, political context, and other technological development and adoption. Therefore, the research products should account for various socio-technical transitions.
BC4	The research products are exploratory in their application and are not to be used as a prescribed method to integrate lean thinking in sustainability transitions in healthcare.	-

4.3 SUITABLE RESEARCH PRODUCT SELECTION

This section identifies research products that are suitable for using lean thinking to facilitate and support sustainability transitions in healthcare. In the following sub-section, possible research products are described to understand the available approaches. The identified research products are compared by evaluating them against the specifications provided by the requirement specifications.

The characterisation of the possible research products is provided in Table 16. To determine which research products are most suitable, the different options are measured against the requirement specifications selected since they determine a research product's identification. A framework is the best approach to the main objectives of this research. The framework is the only approach that is deemed viable when considering the requirement specifications as provided in this chapter.

Table 16: Different research products

Research products	Description
Framework	A general framework is a broad summary, outline, or skeleton of interlinked items (for example, systems, concepts, or texts) which support a particular approach to a specific objective. It is a network of interlinked concepts that comprehensively understand a phenomenon. The constituent concepts of a conceptual framework support one another, articulate their respective phenomena and establish a framework-specific philosophy (Jabareen, 2009).
Roadmap	A roadmap is a plan, or a strategy intended to attain a particular goal by defining the goal (or desired outcome) and including the significant steps required to reach the goal (ProductPlan, 2021). A roadmap contains a high-level plan, defining the overarching strategic objective and capturing the significant steps (Petrick, 2008).

Research products	Description
Theoretical Model	A theoretical model presents an abstract description of a given system (Achinstein, 1965). It is a simplified or idealised portrayal or conception of a particular system, situation, or process, often in mathematical terms. A theoretical model is a foundation for theoretical or empirical understanding, calculations, and predictions. It is a conceptual or mental illustration of something (Oxford English Dictionary, 2021).
Logic Model	A logic model depicts how effort or initiative is believed to work. It describes why a strategy is a solution to the problem faced. Effective logic models make a detailed, often visual, statement of the activities that will constitute a change and the results expected to be observed by the community and people (Taylor-Powell & Henert, 2008). A logic model incorporates the following components: purpose, context, input, activities, output, and effects (Taylor-Powell & Henert, 2008).
Maturity Model	A maturity model conceptually represents phases of increasing a maturing element's qualitative or quantitative capability changes to assess its advances concerning defined focus areas (Kohlegger *et al*., 2009).
Toolkit	A toolkit is a collection of tools designed to be used together for a specific purpose. A toolkit is a fixed collection of procedures, guidelines and criteria that are instituted to ensure the desired result or prevent oversights (Collins Dictionary, 2021).
Blueprint	The term “blueprint” is derived from the architectural domain, which means “detailed plan of action” (Collins Dictionary, 2021).
Strategy	A strategy depicts the process in which a specific problem is approached. A strategy defines the way to get things done but is less detailed than an action plan ((Nagy & Fawcett, 2021).
Typology	A typology is the selection of several combinations of groups of variables. The selection may be based on the data afforded by empirical research (Capecchi, 1968).

4.4 CHAPTER 4: CONCLUSION

This section gives in-depth explanations of the different types of requirements needed for the assessment tool to operate. The identification of these specific requirements is used to ensure that the assessment tool functions as originally intended. The following section, Chapter 5, will concern the functional analysis of the research products.

CHAPTER 5: TRANSITION APPROACHES

This research aims to develop and present a comprehensive framework by integrating the best practices of the two concepts of lean thinking and sustainability transitions in relation to the healthcare system. Furthermore, the framework aims to include the implementation of lean thinking to facilitate and support sustainability transitions in healthcare. This section consists of the functional analysis phase, as illustrated in Figure 18. The identified system is defined in terms of the requirement specifications identified in the previous section and intervention strategies that may be used in solving the specific requirement specifications.

This section provides a synthesis of the three key areas of this research, namely sustainability transitions, healthcare, and lean thinking. The process of obtaining these synthesised sources includes conducting an in-depth literature analysis to identify the relationship between these three areas and identifying aspects that can be used for the final synthesis step, which is the incorporation of lean thinking, conducted in Section 5.4.

At the beginning of this chapter, the framework's purpose, the framework development approach, and the construct guidance of the framework are discussed. The developed framework, of which the development is guided by the set of requirement specifications highlighted in Chapter 4, is presented. The intervention strategies for the requirement specifications are presented to fulfil RO3 (refer to Section 1.3).

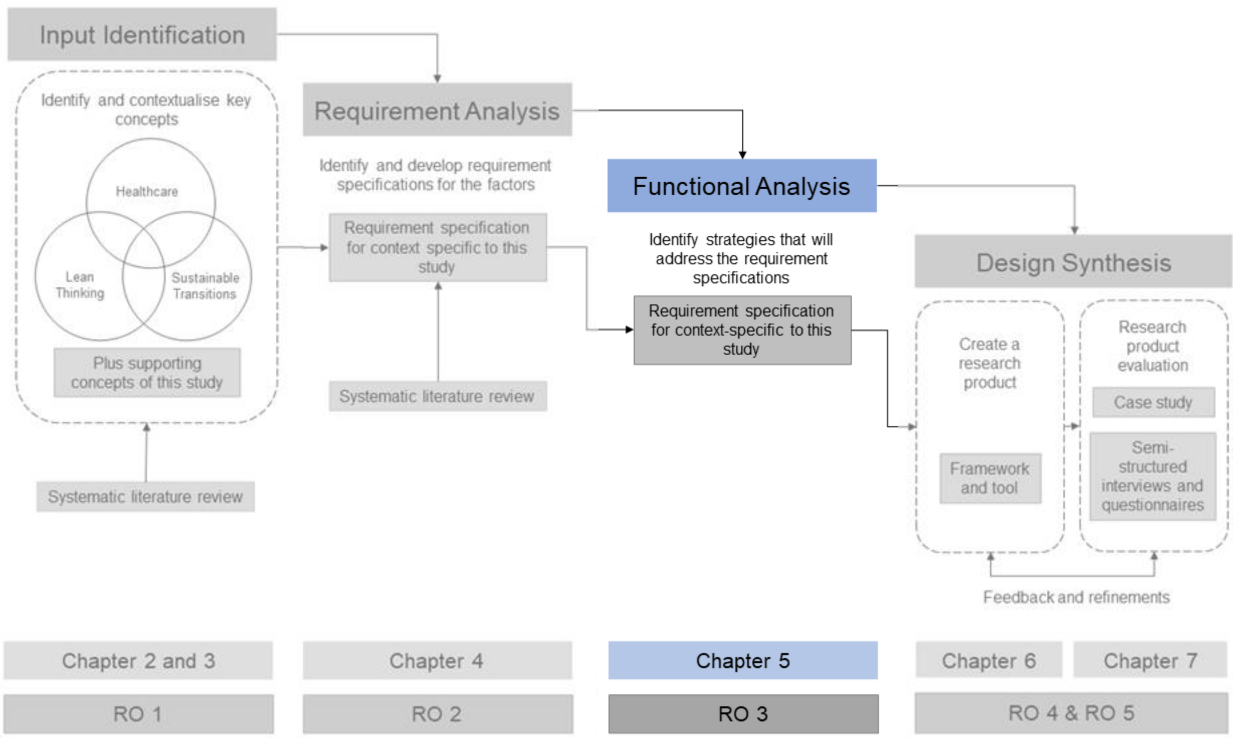


Figure 18: Functional analysis of adapted systems engineering approach

5.1 FUNCTIONAL ANALYSIS APPROACH

The functional analysis process is where the system is defined by its functions by translating the requirement specifications into operational functions (United States Government, 2001). The aim of the functional analysis within the context of this research is to identify these operational functions, also referred to as intervention strategies (Cogan, 2012), which will address the requirement specifications, and subsequently form part of the foundation features of the research products. The functional analysis is conducted by using the triangulation method, which is the practice of using multiple sources and approaches to enhance the credibility of the research (Hastings, 2012). The triangulation method was conducted using the following approaches to identify possible intervention strategies: (i) consulting literature and (ii) using knowledge gained from SMEs.

The functional analysis is conducted by consulting literature whilst considering the requirement specifications, using knowledge gained from literature and having discussions with SMEs.

The first step entailed using insight gained from the literature regarding the specific requirement specifications. This step involved consulting literature used during the development of the requirement specifications. During the functional analysis, intervention strategies were identified by decomposing the higher-level requirements into lower-level requirements. Each lower-level requirement specification was individually considered, and possible intervention strategies were identified that could aid in addressing the requirement in question.

The second step entailed using knowledge from a systems engineering perspective to identify possible intervention strategies for each of the requirement specifications identified. This step entailed addressing each requirement specification individually and identifying possible intervention strategies that can adequately address the requirement in question, similar to the previous approach.

Using these methods, as discussed above, specific intervention strategies were identified that could address the different requirement specifications (refer to Table 29 in Chapter 6.2). The development of the framework is guided by systems thinking and the systems engineering approaches outlined in Chapters 1 and 2. According to Kasser, John and Weng (2008), systems engineering is applicable to numerous systems. It provides a general yet meticulous approach that guides the development of systems that function in an integrated nature. With a typical systems engineering process, the framework development approach involves identifying a set of requirement specifications that have to be fulfilled by a conceptualisation that constitutes the theoretical construct before the proposed conceptualisation is evaluated.

5.2 TRANSITION APPROACHES

Researchers and practitioners have directed much attention towards the increase in environmental concerns and highlighted the need for multiple actors in a system to increase the rate of sustainability transitions (Geels, 2019; Lynch *et al*., 2020). The research on transitions has expanded over the past three decades (Markard *et al*., 2012; Köhler *et al*., 2019). It has evolved from shaping technology and social changes into a multi-disciplinary social science field dealing with the increasing importance of social and environmental sustainability (EEA, 2019). The initial focus of sustainable transitions was in the electrical and transportation sectors but has now expanded to other domains, including healthcare (van den Bergh & Botzen, 2020). Given that environmental and social challenges are recurring events, it is likely that research about transitions will remain relevant and become increasingly important (Markard *et al*., 2020).

A business model is a tool that has received much attention in the literature because it is an actor that includes system-wide sustainability transitions (García-Muiña *et al*., 2020). A business model is a tool that represents the operations of the company to gain a competitive advantage while including and involving all stakeholders (Pateli & Giaglis, 2004; Wirtz *et al*., 2016). A sustainable business model incorporates strategies and concepts to pursue sustainability, and it integrates sustainable principles or circularity into the value proposition, value creation, activities, and value capture (Bocken *et al*., 2016). Circular business models focus on two key factors. “Slowing the resource loop" by extending the use of a material or component in a product, and "closing the resource loop" entails capturing value from end-of-life material (Bocken *et al*., 2019; Sumter *et al*., 2020).

Sustainable transitions can be supported by sustainable business models by acting as a facilitator of the commercialisation of more sustainable technologies (Jolly *et al*., 2012; Elmustapha & Hoppe, 2020) or as a source for promoting non-technological innovations (Bidmon & Knab, 2018). Transition thinking is a methodology that requires a systems thinking approach, which includes theoretical products, frameworks, and approaches to understand socio-technical transitions better. The currently available literature highlights the understanding of how to address challenges that are being faced by socio-technical systems adequately. However, the literature is unclear about agents, activities, or actions that could aid in and promote transitions (Doci *et al*., 2015).

Socio-technical transitions are transformations of socio-technical systems, including long-term processes that shift transitions to establish new, original socio-technical ideas. Research indicates that these transitions aim toward more sustainable futures (Loorbach, 2014; Markard *et al*., 2012). This is because the concept of "transitions" has been gaining a substantial amount of momentum in the field of "sustainable development", which was triggered by the World Commission of Environment and Development during the 1980s (Lachman, 2013). Socio-technical transitions have been implemented throughout the development of humanity. Some historical examples include the transformation of sailboats to steam engines, horse carriages to cars, and the introduction of pipe-based water supply systems (Geels, 2005). When evaluated from the triple-bottom-line perspective, it is evident that all historical socio-technical transitions do not promote more sustainable futures (Elkington, 1994). Socio-technical transitions are also associated with sustainable goals as their focus is on implementing system shifts to more sustainable methods of resource use during production and consumption phases (Markard *et al*., 2012). It can be concluded that the aim of sustainability transitions focuses on the sustainability of a socio-technical system using technological, social, and political intervention strategies (Rotmans *et al*., 2001). The increased understanding and application of socio-technical transitions can aid in tackling unsustainability by understanding, conceptualising, explaining, and identifying how socio-technical transitions change to more sustainable states. Socio-technical transitions require various innovative techniques to reform existing socio-technical transitions into more sustainable ones. Researchers have identified three interactive levels recurrent in socio-technical transitions, defined as "niches, regimes, and landscapes." For a transition to occur, all three interactive levels must undergo simultaneous change or development (Geels, 2002).

Transitions can occur through regime change or transformation. Regime changes are evident when the current regime cannot adapt to the pressures of the landscapes and niches. The regime is then replaced by another capable of dealing with the landscape and niche pressures. Regime transformations are evident when the current regime responds to landscape and niche pressures whilst changing certain regulations within the regime to enable it to accommodate the recent changes (Bergman *et al*., 2008). The healthcare industry has long been a clear indication of well-being within the direct modern community. This industry faces the challenge of needing to be able to adequately address critical problems without fundamental changes occurring (Broerse & Grin, 2017). However, the available literature resources on sustainable transitions in healthcare all had the common goal of achieving a global culture and active engagement in continuous quality improvement (Broerse & Grin, 2017)**.** Implementing lean within healthcare institutes globally all have a common challenge in achieving higher levels of sustainability. Research indicates that "experimentation is an important capability in the transition to a sustainable business". These experiments aim to improve the current level of innovative activities in business models despite the limited resources available. The circular economy[1] is the primary driver of sustainability (Bocken *et al*., 2018).

Numerous multi-disciplinary approaches exist that study socio-technical transitions. Approaches that have been used thus far are: (i) the multi-level perspective (MLP), (ii) strategic niche management, (iii) transition management, (iv) innovation systems, (v) techno-economic paradigm, and (vi) socio-metabolic transitions (Van Den Bergh *et al*., 2011). Scholars also provided four frameworks that achieve prominence in transition studies, considered central to the theoretical framing of socio-technical transitions. These frameworks are (i) transition management, (ii) strategic niche management, (iii) MLP, and (iv) technological innovation systems (TIS). It is evident that MLP, innovation systems (specifically TIS), strategic niche management, and transition management are the most distinguished approaches when studying socio-technical transitions (Markard *et al*., 2012). This study includes the approaches of "Forces for Change", which is synthesised with MLP, "Transition Failures", "The Resilience of Sustainability Transitions (RST)", and "Transition Pathways". The inclusion of these four approaches is necessary to gain a deeper understanding of where lean thinking can be implemented to support sustainability transitions.

To gain a deeper understanding of sustainability transitions, seven approaches have been selected for this study, being:

i. Forces and conditions for transitional change in synthesis with MLP (to understand and identify how lean thinking could contribute to supporting *landscape tensions*, *regime stress*, and *niche pressure*);
ii. Transitional and Transformational Failures (to understand and identify how lean thinking can support the occurrence of different *transition failures*);
iii. Innovation System Approach (to understand and identify how lean thinking can support *system weaknesses* in the study of sustainability transitions);
iv. Strategic Niche Management (to understand and identify how lean thinking can support the *introduction and diffusion of new sustainable technologies* through societal experiments);
v. Transition Management (to understand and identify whether lean thinking can be used at a *strategic, tactical, operational,* or *reflexive level*);
vi. RST (to understand and identify how lean thinking can be used to support *progress, stability,* and *adaptability*; and
vii. Transition Pathways (to understand and identify how lean thinking can support different *transition pathways*).

5.2.1 FORCES AND CONDITIONS FOR TRANSITIONAL CHANGE

According to Geels (2003), the Multi-Level Perspective (MLP) is an "analytic and heuristic concept to understand the complex dynamics of socio-technical change". MLP is illustrated in Figure 19 below. The MLP is effectively used as the dominant framework for the analytical analysis of Socio-Technical Transitions (STTs). Geels has further expanded this framework since its development by Kemp *et al*. (1998). The expanded Geels MLP framework serves as an analysis tool for STTs, which provides an analytical understanding of the structure of Socio-Technical Systems (STSs). The Geels MLP framework provides an in-depth description and understanding of how transitions occur. MLP confirms that a multi-dimensional interaction between distinct levels of an STS is pivotal to ensure that the system changes towards increased sustainability. MLP addresses two core challenges of transitions, namely, the occurrence of change and stability. Lock-ins and path dependencies are also characteristics of internal dependencies for transitional shifts (Geels & Kemp, 2012). According to Geels (2003), the further development of the MLP occurred by using the landscape regime and niche dimension. Geels (2003) agrees that the MLP is a complex study, yet it helps analyse shifts in STSs toward increased sustainability. Radical technology innovations occur within "*niches",* making small disturbance waves in the STS, thus providing the space and location for actors to allow growth and development of social networks leading to supported innovations. "*Regimes"* are logically ordered and integrated by various social groups, and it accounts for the stability of the STS by orientating and coordinating activities relevant to the specific actor groups. Innovations occur in small increments within *"regimes"* (Geels, 2003). *"Landscapes"* set the external environment within which the niches and regimes function. It includes technological pathways and slow-changing diverse factors, often difficult to change where long-term goals and targets are set for a system transition (Geels, 2003). It can be concluded that transitions are not caused by changes from a single factor in the system but are driven by actors across many processes and operations in a system.

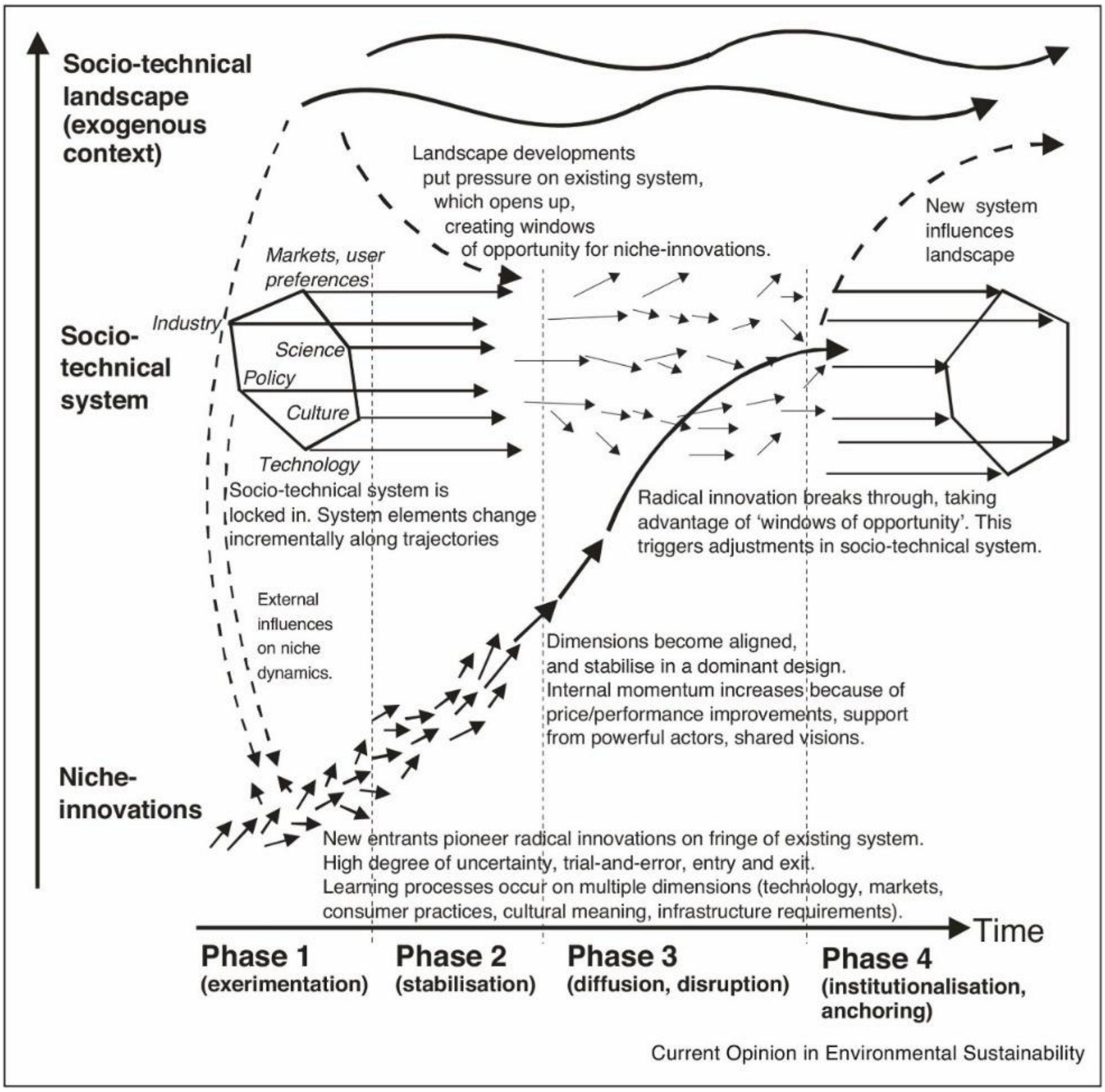


Figure 19: Geels' MLP framework for understanding STS transitions (Geels, 2003; Geels, 2004; Geels, 2005).

Transitional change requires an existing regime to transform from the original state to a new or alternative state which is more sustainable. Regime change has the function of changing selection pressures on a regime whilst coordinating and managing available resources to change the regime and its functionality to the landscape (De Haan, 2010).

Drivers of transitional change are recognised by De Haan (2010) and illustrated in Table 17 as:

i. Tensions with the landscape (the mismatch between the function of the regime and the developments of the landscape);
ii. Stress within the configuration (internal mismatches within the regime); and
iii. Pressure from the configuration (the mismatch with new niche innovations and functions).

From the offset of the implementation of transitions, the conceptualisation of the conditions (Frantzeskaki & De Haan, 2009; Van Den Bergh *et al*., 2011).

Table 17: Forces driving and conditions for transitional change (De Kock, 2020; Frantzeskaki & De Haan, 2009)

Forces driving transitional change		Conditions for transitional change	
Tension	↓	Top-down force	A mismatch between the functions of the regime and landscape.
Stress	♻	Internal	Internal mismatch of the function of the regime.
Pressure	↑	Bottom-up force	The pressure of a competitive alternative to the regime function.

The forces driving transitional change set the foundation for the three conditions, and the conditions need to be understood and identified to gain a deeper understanding of the dynamics of the transitions. Either these forces can contribute towards the increase in transitional change, or they can suppress it. This is in line with transitional progress depending on the drivers for system change and the resistance to system change (Schilling *et al*., 2018). These forces are clustered into three groups, i.e., formation, support, and triggering forces, depending on their interactions and their contribution towards either hindering or enabling the transition. The impact of these forces is illustrated in Table 18 below.

Table 18: Forces driving transitional change (De Kock, 2020)

	Direction of change			Clustering of forces influencing transitions		
Forces driving transitional change	↓	♻	↑	**Formation Forces**	**Support Forces**	**Trigger Forces**
Crises, exogenous events	x					x
Standardisation of practices/routines	x				x	
Provision of resources	x				x	
Exercise of power (over the system by external or internal centres of influence)	x				x	
Imposition of a new functioning	x					
Systemic failures		x				x
Self-regulation of the system		x			x	
Presence of a niche			x	x		
Presence of a new demand			x	x		
Presence of a new functioning	x		x	x		

A multi-level perspective (MLP) is a method in which a regime transition occurs because a landscape level puts pressure on the regime to support change or improvement. The regime level coordinates the resources to adapt to the landscape pressures (tension & top-down). The regime-level developments open "*windows of opportunities for niche innovations to break through the regime*" (Geels, 2005). The niche and landscape levels can be "*derived concepts*" as they are defined within the context of the regime. The niches are practices or technologies that vary from the existing regime (pressure & bottom-up). The landscape is the external environment that influences the niches and regime-level interactions. For example, in Greece, their healthcare systems introduced a new information system for health coordination and governance, which occurred due to the developments in the socio-technical regime (Vassilakopoulou & Marmaras, 2015). Pressure from the landscape level is exerted on the weak health governance regime to support reform. These changes in the health governance regime allow for innovations that could address the prevalent problems in the incumbent health governance regime. These forces transform into principles or institutional "*logic*" that shapes how the institution is organised, how the roles and identities are performed and defined, and how the actors behave. This suggests that the experiences of standardising and normalising changes in the healthcare system can reflect the workings and implications of the regime transition process (Macabasag *et al*., 2022).

Experts and key leaders in academia, medicine, the pharmaceutical industry, philosophy, psychology, technology arenas, and non-profit organisations gathered in a discussion session where ideas and critical points regarding the new XXI century challenges in healthcare were discussed. They aimed to design a vision for renewed healthcare systems. Their considerations started by using the structure of a healthcare system as defined by WHO, which considers "*service delivery, health workforce, health information systems, access to essential medicines, financing, and leadership or governance*" while following the key points and issues highlighted by each other (Organization WH, 2010). The features of sustainable, inclusive healthcare systems were summarised into six actions, also called the drivers for change, to improve healthcare systems and to support transitions towards it. Actions to be taken to reach the objective have also been highlighted by the experts (Blasi *et al*., 2022). Tables 19 to 21 below illustrate current relevant healthcare landscapes, regimes, and niches.

Table 19: HC landscapes (adapted from (Canyon *et al*., 2010; Behrends *et al*., 2022; Edwards & Grinspun, 2011; National Department of Health, 2011))

HC Landscapes (Top-down force & Tension)	**Broader political, economic, and demographic trends**	**Crises, exogenous events**
		Infrastructure collapse, diminished function, impaired outcomes for patients and lack of safety for staff and patients
		Threats of terrorism, litigation, and threats to personal safety and reputation
		Global pandemics and climate change
		Product recall, product tampering, and employee sabotage
		Fires, explosions, and chemical spills
		Lawsuits and incidents about the loss of confidential information
		Standardisation of practices/routines
		COHSASA Healthcare Standards: statements that define the functions, activities, processes and structures and systems required for organisations to be able to provide safe, high-quality services.
		Patient rights: ensure that patients are respected and that their rights are upheld (including obtaining access to needed care in a respectful, informed, and dignified manner).
		Patient Safety, Clinical Governance & Care: ensure quality nursing and clinical care and ethical practice, reducing unintended harm to healthcare professionals and patients. Prevent and manage adverse events, including healthcare-associated infections.
		Clinical Support Services: services provided by clinical care which include the availability of medicine and other resources, and the efficient provision of diagnostic, therapeutic and other clinical support services, as well as systems which monitor the efficiency of the care provided to patients
		Public Health: this covers how healthcare facilities should work with non-government organisations (NGOs) and other healthcare providers and services to promote health, prevent illnesses, and reduce complications. Ensure that integrated and quality care is provided for the whole society, including during disasters.
		Leadership & Corporate Governance: the strategic direction provided by management through proactive leadership, planning and risk management which is supported by the healthcare board, clinical committee, and other supervisory support structures (this includes the strategic functions of communication and quality improvement)

HC Landscapes (Top-down force & Tension)	Broader political, economic, and demographic trends	**Standardisation of practices/routines**
		Operational Management: the daily responsibilities involved in supporting and ensuring the delivery of safe and effective patient care, which includes the management of human resources, finances, assets and consumables and other information
		Facilities & Infrastructure: clean, safe, and secure physical infrastructures and functional well managed services.
		Provision of resources
		Access to healthcare services between urban and rural areas
		Quality of healthcare services between urban and rural areas
		Inequitable resource allocation between urban and rural areas
		Exercise of power (over the system by external or internal centres of influence)
		The interpretive combination of existing, qualitative healthcare policy analysis literature generates policy relevant to insights about the processes and practices of policy change.
		The micro-practices of power, which are exercised by frontline workers' discretionary power, must be combined with efforts to influence healthcare professionals by aligning resources and environments with policy goals to influence the discourse and mindsets, beliefs, and values in healthcare providers.
		International agencies whose institutional roles and resources can shape the goal action on healthcare.
		Political parties can influence the equity and universality of public policies.
		Administrators, bureaucratic agents, and frontline workers
		Imposition of a new functioning
		Increased attempts at improving sustainability in healthcare (achieving the SDGs)
		Quality should be ingrained in all healthcare systems because the human right to healthcare is meaningless without good quality care.
		Health systems should measure and report what matters most to people, such as competent care, user experience, health outcomes, and confidence in the system.
		New research is crucial for the transformation of low-quality health systems to high-quality ones.
		Improving the quality of care will require system-wide action.

Table 20: HC regimes (adapted from (Hartmann *et al*., 2021; National Institute of Health, 2011))

HC Regimes (Internal force & Stress)	Industry, culture, policy, science, user preference, technology	**Systemic failures**
		Moving up or down the hierarchy: most healthcare systems are structures to provide care at a lower cost. Higher skills and specialisation correlate with more costly and generally more extensive facilities, such as specialised clinics and hospitals.
		Medical errors: the reduction of medical errors in a systemic way by using principles of the Toyota production system can lead to the elimination of infections.
		Patient errors: wrong site, wrong time or date, disobeyed pre-treatment instructions, incorrect paperwork.
		Operational environment: Patients with insufficient financial means for treatment, queues, supply chain and inventory management, staff unavailability, delays from support or diagnostic services, and lack of infrastructure.
		Self-regulation of the system

Table 21: HC niches (adapted from (314e, 2021; Institute of Medicine (US) Committee on Quality of Health Care in America, 2001; Deloitte, 2022))

HC Niches (Bottom-up force & Pressure)	**New technologies, business models, and behaviours**	**Presence of a niche**
		Hospitals and healthcare systems: the desire to build an integrated system and disparity Many systems have high operating costs.
		Ambulatory surgery centres (ASC): movement of surgery procedures from hospitals' outpatients' departments to ASCs' reduced spending
		Urgent care: typically, services are cost-effective because they cost less than those provided at hospitals.
		Home healthcare: hefty costs and governmental scrutiny for the home healthcare industry.
		Skilled nursing facilities: nursing homes have encountered payment cutbacks due to the reduction of staff and increased risks about financial, regulatory, and litigation risks.
		Medical devices
		Rehabilitation and addictive treatment
		Hospital-based specialists: hospitals can effectively reduce the time demands on revenue-generating physicians. The potential to decrease liability costs is associated with the continuous presence on-site.
		Health information technology: increased efforts are implemented to utilise data which is present in new technologies deployed in healthcare.
		Focus on a use case for strategic healthcare information technology (IT): IoT technology can be used to keep an eye on "Frequent Flyers" via a monitoring tool or wearable that can provide a return on investment that more than covers the cost of implementation.
		Presence of a new demand
		Healthcare professionals, policymakers, purchasers, regulators, healthcare trustees, healthcare management, and consumers commit to a statement of purpose for the healthcare system as a whole and to a shared view of 6 aims for the improvement that can increase the quality of care.
		The Department of Health identifies priority conditions that focus on initial efforts, provide sufficient resources to stimulate innovations, and initiate the changing process.
		Purchasers, regulators, healthcare professionals, educators, and the Department of Health create an environment that promotes and rewards improvement through (i) the creation of infrastructure that supports evidence-based practice, (ii) facilitation of information technology, (iii) aligning payment incentives, and (iv) preparation of the workforce to increase their quality-of-service delivery to patients in a world with expanding knowledge and rapid changes.
		Share data across all sectors in real-time: public data systems in healthcare should enable cross-sector real-time data sharing forming linear data that can cut across public health concerns.
		Centre future public health around health equity: placing equity in the centre of public health goals, incorporating health equity measures into public health initiatives from the start, and increasing the diversity, equity, and inclusion into the workforce. Empowering the community to lead change and build equitable health metrics into funding and national guidelines.
		Presence of a new functioning
		The use of artificial intelligence (AI) and the Internet of Medical Things (IoMT) encourage healthier behaviours and assist in the proactive management of healthy lifestyles. It puts the patient or customer in control of their health and well-being.

5.2.2 TRANSITIONAL AND TRANSFORMATIONAL FAILURES

Systemic transformation, within the context of sustainability transitions, highlights the need to understand how to evaluate continuing transition progress (a transition that no longer undergoes progress and thus stops and fails), as well as the resilience of the sustainability transition over a period (Mühlemeier *et al*., 2017). A transition's success depends on multiple facets, and only recently have the enablers and drivers for transitional change been addressed (Panetti *et al*., 2018). To better understand a resilient or successful transition, "failed transitions" are considered and described by several scholars (De Haan, 2010; Van Der Brugge & Rotmans, 2007). Figure 20 below illustrates the different types of transitional failures.

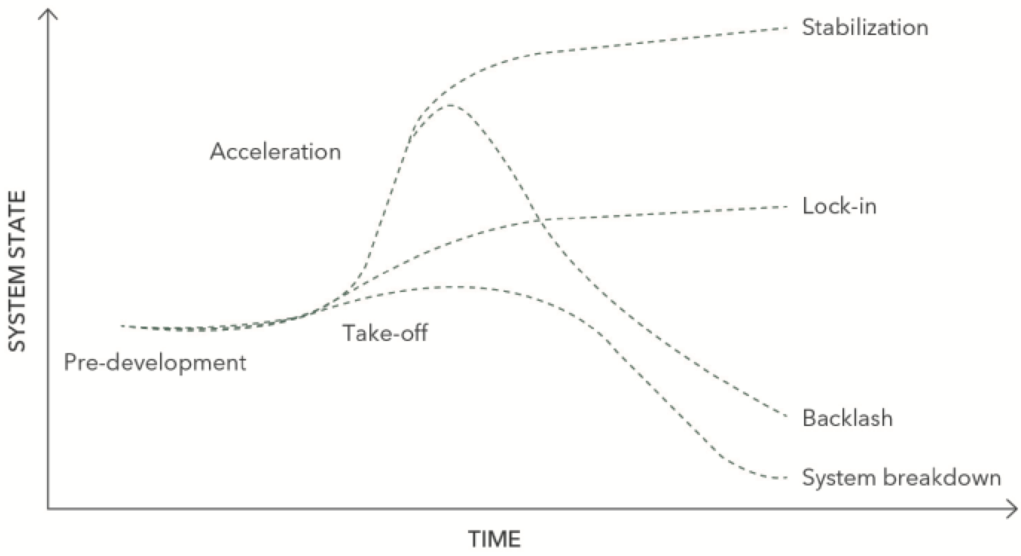


Figure 20: Possible system pathways (adapted from (De Kock, 2020; Van Der Brugge & Rotmans, 2007))

Transition failures depend on whether a transition undergoes progress and changes from one transitional phase to the next. Three transition failures are described, which relate to transitions that do not reach a new or alternative, more sustainable system state (stabilisation). These transition failures include (i) lock-ins, (ii) system breakdown, and (iii) backlash. Table 22 below describes these types of transition failures.

Table 22: Transition failures (Van Der Brugge & Rotmans, 2007)

Transition Failure	Description
Lock-in	*"A transition path where an innovation does gain influence in the societal system but fails to completely replace the regime co-existing with it in a locked-in state. Lock-ins occur when the unsustainable (incumbent) regime remains to co-exist alongside competing innovations, or when competing innovations co-exist but none of these innovation networks are powerful enough to stabilise as the new regime, thus creating a lock-in of innovations".*
System breakdown	*"A system breakdown refers to the event where there are no innovation networks available that become self-sufficient, and all innovation networks continue to compete for the same resources; this results in no viable alternative being available. Alongside this, a regime is destabilising, meaning that it can no longer fulfil the societal functions. However, because no alternative is available, the system breaks down."*
Backlash	*"When niches that initially gained power and popularity, and thus progressed to the 'take-off' phase, subsequently fail to become the mainstream practice to meet societal needs, the system experiences backlash. This can happen if, for example, the demand for a certain functioning increase quickly, but the niche is unable to cope with such drastic increases in demand and/or changes in demand, and thus fails. In another scenario, some novel functioning could be initially adopted by many, until unexpected challenges arise, and the niche is no longer adopted by users as a mainstream practice; in this case too, backlash can occur."*

Failure in the context of transformational change considers that when a transformational change of a socio-technical system occurs, and the long-term and fundamental characteristics of the transition process are questioned and studied, alternative failure instances must also be considered (Weber & Rohracher, 2012). Four transformational failures are proposed (i) directionality failure, (ii) demand articulation failure, (iii) policy coordination failure, and (iv) reflexivity failure. These types of failures pertain to failures that affect transitional progress in socio-technical systems. These failure types are discussed in Table 23, along with examples of overcoming these failures and examples of mechanisms that lead to the occurrence of the type of failure.

Table 23: Transformational failures (Walrave & Raven, 2016; Weber & Rohracher, 2012)

Description	Examples of overcoming these failures	Examples of key mechanisms that lead to the occurrence of the failure
Directionality failure		
Directionality failure pertains to the observation that a need to consider the direction of innovation in such a way that the innovation contributes towards societal challenges exists. These failures are also associated with one being locked-in in a particular solution that could be more optimal in a long-term perspective.	Guiding orientations should be translated, and the intermediation of guiding orientation should be implemented to overcome directionality failure. External requirements to the innovation system must be absorbed, interpreted, and negotiated to provide direction for the relevant actors.	i. Lack of shared vision regarding the goal and direction of the transformation process; ii. The incapability of collective coordination of actors that are involved in the shaping of systemic change; iii. A lack of sufficient regulations and standards to guide the direction of the systemic change; and iv. Insufficient targeted funding for research and development, projects, and infrastructure that can facilitate the development of acceptable development paths.
Demand Articulation Failure		
Demand articulation failures pertain to the observation that markets for innovations (technologies specifically) may not (yet) exist and could result in a lack of articulation of what these markets require or what user preferences are (results in a lack of being able to anticipate user needs).	Support learning processes that involve produces and users (e.g., strategic niche management); more attention on new and neglected forms of innovation; integrating consumers and producers in innovation processes; creating and increasing awareness of new possibilities; innovation-oriented procurement mechanisms; and policy support to facilitate building up the competencies of potential users to articulate their needs and demands.	i. Insufficient opportunities for anticipating and learning about user needs; ii. The lack of orientation and stimulating signals from public demand; and iii. A lack of demand-articulating competencies.
Policy Coordination Failure		
Policy coordination failures refer to the observation that policies and institutional standards may need to transform to respond to the challenges and to support the development of innovations to address these challenges adequately.	It is crucial to ensure coherence between the activities on national, regional, sectoral, and technological institutional levels. The harmonisation of research and development funding and the regulatory environment is essential.	i. The lack of cross-level policy coordination; ii. A lack of horizontal coordination between research, technology, and innovation policies, and on the other hand, sectoral policies; and iii. A lack of temporal coordination could result in misalignment between the timing of interventions and system actors.
Reflexivity Failure		
Reflexivity failures refer to the observation that there is a need to monitor the development of technology innovations continuously, with regards to such systems' contributing to the broader development of adaptation strategies.	The provision of platforms for interactions and opportunities for experimentation, monitoring and learning among different actors and platforms; learning by the actors by reflecting on the conditions for change and engagement in the transformation of the systems in which they operate.	i. A lack of monitoring, anticipating, and inclusion of actors in processes of self-governance; ii. A lack of distributed reflexive arrangements to connect different sectors to provide opportunities for experiments and learning; and iii. A lack of adaptive policies allows for policy options to be kept open to deal with uncertainty.

5.2.3 INNOVATION SYSTEM APPROACH (ISA)

Innovation systems consist of networks of actors that influence and determine the direction and speed of technological change in socio-technical regimes. The approach, however, takes on a broader view than technological change. The systemic context of the technological changes and innovations takes into consideration innovating actors, interaction networks and the dependence and interdependence of it on various institutions (Edquist, 2005; Hekkert *et al*., 2007). The innovation system approach has also been defined and elaborated at various levels of analysis, namely National Innovation Systems (NIS), Sectoral Innovation Systems (SIS), Technological Innovation Systems (TIS), and Regional Innovation Systems (RIS) (Jacobsson & Bergek, 2011). These approaches are different regarding the system boundaries, but they share certain features, like the fact that the innovation and diffusion process is a collective and an individual act. The most important contribution of innovation system approaches is that it provides policymakers with a tool to identify system weaknesses in the study of sustainability transitions. It highlights problems that require intervention to promote the system's development or influence its direction. Primarily TIS has been used to study the emergence of modern technological innovations. The TIS focuses on the characteristics of a system associated with technological innovations. It aims to identify and analyse the characteristics associated with the strength and weaknesses of the technologies, and it also compares the system with the dominant or other competing technology in the existing socio-technical regime (Hekkert & Negro, 2011). This approach aims to separate the innovation systems into components to identify which do not realise the intended purpose or achieve the desired targets. These elements will damage the development process of the entire system (Jacobsson & Bergek, 2011).

TIS consists of 7 sub-functions:

i. Knowledge development and diffusion, which strengthens the extent and the depth of knowledge and how this knowledge is developed, diffused, and combined in the system;
ii. Entrepreneurial experimentation, which strengthens the testing of modern technological innovations, applications, and markets where new opportunities are created, and the learning process unfolds;
iii. Influence on the direction of search, which strengthens the incentives and pressure for organisations to enter the technology field, which can come in the form of a vision, expectations of development potential, regulations, articulation of demand from leading customers, or crises;
iv. Resource mobilisation, which strengthens the extent to which actors within TIS can mobilise human and financial resources and complementary assets (such as network infrastructure);
v. Market formation, which strengthens the actors which drive the market formation and includes the articulation of demand from the customers, institutional changes, and changes in price or performance;
vi. Legitimation, which strengthens social acceptance and compliance with relevant institutions; and
vii. Development of positive externalities, which strengthens the collective dimension of innovation and diffusion processes (how investments by one firm can benefit other firms "free of charge") and indicates the system's dynamics.

5.2.4 STRATEGIC NICHE MANAGEMENT (SNM)

SNM focuses on the initial stages of adopting niche creation (through experiments) that can contribute towards sustainable development. The approach creates protected spaces that can support the development process of technological innovations. This approach aids in understanding how and under what circumstances the successful emergence of a technology niche is possible (Schot & Geels, 2008). This approach focuses on aligning technological innovation through the SNM process to change the regime. SNM evaluates the required measurements that increase the probability of a niche technology replacing the existing unsustainable (incumbent) technology within the socio-technical system (supporting socio-technical transition) (Raven & Geels, 2010).

A few insights into SNM are:

i. The management of the niche process: niche managers should practice community-building by sharing knowledge, arguments, disagreements, and talks while involving negotiations, games, competitions, etc. The early participation of all team members is essential to SNM;
ii. The commercialisation of successful niche technology: the smooth handover of new technology through research and development experiments in the niche market. The team should undergo continuous learning by analysing markets and feedback regularly. Other aspects include teaming up with established manufacturers, offering a variety of products to attract a larger clientele, offering trial packages or hire purchases for non-visible products and services; and
iii. The policy management of the breakdown of protection: establish clear targets that become more ambiguous over time and penalties when these targets are not met. These rules should be clearly communicated.

5.2.5 TRANSITION MANAGEMENT

This approach aims to work towards sustainability while adding to ongoing movements to aid in controlling and building bottom-up initiatives. It is strategic to exploit the ongoing development process and dynamics to guide the system towards a more sustainable future or specific SDGs. A potential target could be to use a specific technological innovation or another performance indicator. This approach works towards achieving system improvements and system innovations. It supports constructively dealing with complexities and uncertainties. It is based on a process management philosophy that directs the existing or new process towards a specific goal set or certain targets desired in the future. Key components of transition management are long-term thinking, back-casting, multi-level thinking, multi-domain thinking and analysis, focus on learning, orientation towards system innovations and evaluating various situations. The main aim of this approach is to identify and analyse opportunities, enablers, limitations, and conditions under which transition management has to be set up to influence a socio-technical system to undergo a transition effectively (Elzen *et al*., 2004). This approach is further elaborated upon in Section 2.4 and will be used to assess to which extent the lean thinking approaches and principles could contribute towards supporting the other identified approaches towards the transitions to sustainability.

5.2.6 THE RESILIENCE OF SUSTAINABILITY TRANSITIONS (RST)

Sustainability transitions have been defined as any transition that aims to achieve sustainability goals and “long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shifts to more sustainable modes of production and consumption” (Markard *et al*., 2012). Sustainability transitions have the main goals of enhancing a system’s overall sustainability and creating more sustainable system states that result in a standardised and goal-oriented perspective. The transition towards sustainability requires changes in technology, societal structures, routines, and culture (Markard *et al*., 2012).

The resilience of a system is characterised by the following:

i. Latitude (the degree of a system change that is possible without losing the ability to recover);

ii. Resistance (the level of difficulty of changing the system);
iii. Precariousness (the distance between the current state of the system and the critical point at which the system can no longer recover); and
iv. Panarchy (the influence of cross-scale interactions with systems at scales above and below the system) (Folke, 2016; Holling, 2001).

The resilience of a system state is defined as "*the capacity of a system to absorb disturbance and reorganise while changing to still retain essentially the same function, structure, identity, and feedback*" (Walker *et al*., 2004). According to Binder *et al*. (2017), systems must maintain functionality throughout the entire transition process for the transition to be successful. The system must be resilient to internal and external shocks and challenges.

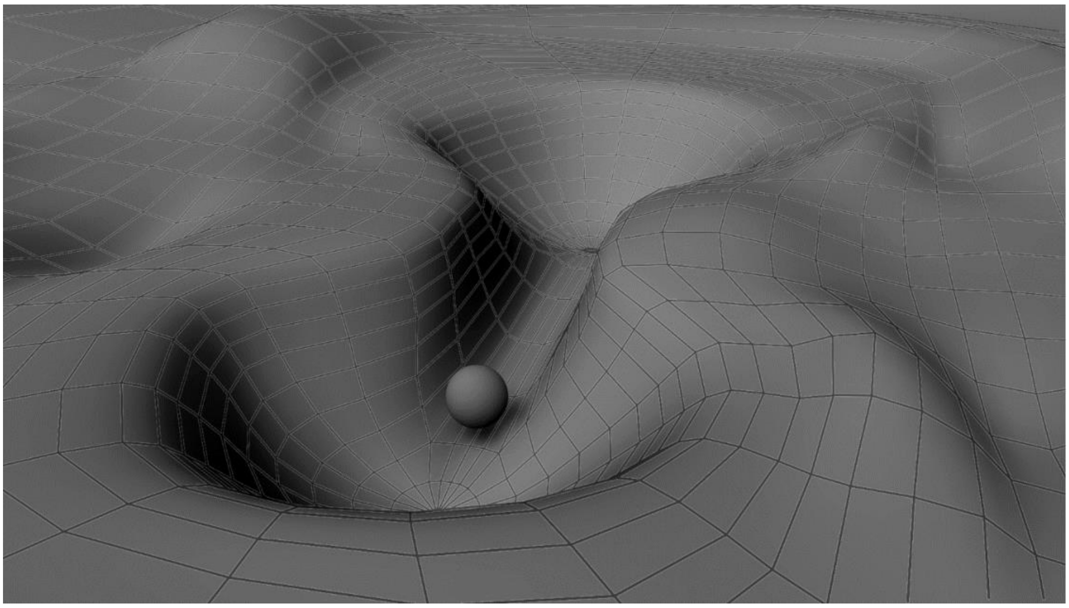


Figure 21: Ideal-typical illustration of a sustainability transition process from a stability landscape perspective (Schilling *et al*., 2018)

The ideal characterisation for a sustainability transition is illustrated in Figure 21, where the system (ball) transforms (rolls) out of the centre of an unstable system state (relatively stable basin of attraction) towards a more sustainable system state (an alternative basin of attraction). The halfpipe shape represents the resistance (the depth of the basin illustrates the ease or difficulty of deviating from the path) and its flexibility (the width of the basin illustrates the amount of deviation that is possible without losing the ability to recover to the original). The overall resilience of a sustainability transition is the capacity of the system to absorb disturbance and adapt to the sustainability transition process while maintaining its progress, goals, and transitional pathway. The capacity depends on factors that form the sustainability transition process's progress, stability, and adaptability (Schilling *et al*., 2018). These three factors are illustrated in Figure 22.

PROGRESS

The most fundamental aspect of a sustainability transition, a dynamic change process, is the degree to which the system transforms in a period. The degree of transformation depends on the system's drivers for change and the resistance against those drivers changing the system. For sustainability transitions, the drivers can contribute to reaching a set of sustainability goals or move the system towards a less sustainable state. These drivers can also differ in the quality of the impact they have on transitional progress. Drivers act as the "fuel" that moves the system (ball), affecting the relative distance between the current and goal systems.

On the other hand, resistance can reduce transition drivers' impact on transitional progress. The creative potential of change agents is limited if system structures are not supporting the establishment of socio-technical niches in which they can function and experiment (Geels *et al*., 2014). Managing the resistance to sustainability transitions is crucial in ensuring its success. Transition management literature refers to "phasing-out" strategies that are introduced to create smooth, non-disruptive processes of transformation, which minimises the negative consequences of obligated system actors while ensuring transition progress (Loorbach, 2014).

STABILITY

The stability of a sustainability transition refers to the capacity of the system actors to deal with uncertainty, respond to unforeseen events, and recover from shocks without forfeiting their original pathway towards sustainability. The elements of a sustainability transition that affects its overall stability are the anticipated system state, with the relevant corresponding sustainability objectives, and the stability of the transition pathway that is supposed to lead to the envisioned state. The stability of the envisioned state depends on different variables, which are the level of specificity of the objectives, the level of clarity, the outreach of communication towards actors, the discerned benefits of the envisioned system state in comparison to the present state, and the acceptance thereof (Spath & Rohracher, 2010). With sustainability as the guiding norm for a transition, the system actors need to correspond in terms of what sustainability means in their system, develop sustainability goals, and create an understanding of the problems that need to be addressed. An elaborated vision of the envisioned goal system state, which is agreed upon within the entire system, can employ a significant amount of attraction and lead to increased stabilisation of the sustainability transition (Binder *et al*., 2016). In uncertain phases of the transition, a solid structured and stipulated vision can re-focus the system on the original goals. To stabilise the transition pathway, support for the sustainability transition is required within the governance system and among the system actors. The governance system is responsible for communicating and enabling transparency, reliability, and consistency within the boundary conditions of the stable transition process (Verbong & Geels, 2007). Transition management needs to be aware of a system's primary compartments and functions to ensure that the risk of a system-level collapse is minimised (Binder *et al*., 2017). The collapse on a sub-systemic level is sometimes necessary to release new potential or innovation and to ensure transition progress which can negatively affect the stability of the sustainability transition process. Adding to the stability of a transition process, it is important to consider that a high level of system resilience and minimal adverse effects associated with disruptive changes in a system must be maintained. Referring to the stability landscape metaphor illustrated in Figure 21, resilient systems function within a stabilising topography, such as the basin of attraction. The extension of a basin of attraction into a halfpipe of attraction enables the maintenance of the stabilising typography at any point during the transition process while allowing for transitional progress to occur along a stable transition pathway (Schilling *et al*., 2018).

ADAPTABILITY

Changing boundary conditions of a sustainability transition can contribute to exposing new possibilities for the sustainability transition. The transitioning process needs to address new situations and respond adequately to support the sustainability transition. A new emerging situation could be identified as a threat or disruption to the original idea, which would require a high level of stability to deal with the threat and recover to the original sustainability transition goal and pathway. On the other hand, the new emerging situation could be identified as a new opportunity to reach even higher levels of sustainability. The new emerging situation can contribute to solving existing problems, or it can contribute to accelerating the process. In this case, it is essential to ensure that the sustainability transition process is adaptable. The degree to which a system is adaptable depends on multiple aspects, which include the governance system, institutionalised and informal exchanges among the different actors, and transition management operations (Engle, 2011). Pathway lock-ins can, however, negatively affect the adaptability of a sustainability transition. To this end, the path dependency of transition pathways is considered (how strongly past developments pre-determine the future evolution of systems) (Cecere *et al*., 2014). Path dependency allows for planning security and stability against external shocks and sub-optimal system state outcomes or other pathway lock-ins. Thus, adaptability is linked to stability in a transition process. The stability of the transition pathway can disrupt the adaptations and lead to transition pathway lock-ins. An adequate balance between stability and adaptability must exist within a sustainability transition in order to ensure that the diverse system actors can benefit from the positive effects of path dependency (stability) while simultaneously preventing the adverse effects of path dependency (lock-ins) (Schilling *et al*., 2018). The importance of the RST dimensions across the transition phases is illustrated in Figure 22.

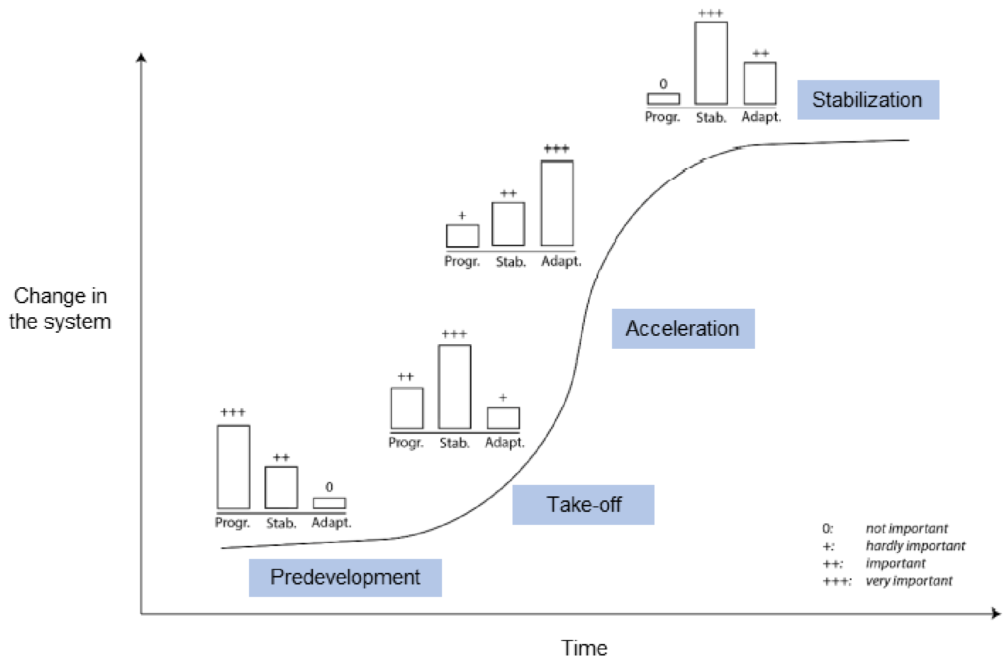


Figure 22: Importance of RST dimensions across transition phases (Schilling *et al*., 2018).

RST AND TRANSITION PHASES

Successful transition is only possible if the relationship between the drivers and resistance of the transition develops in a way which facilitates system change. The "pre-development phase" should pay close attention to the transition "progress" dimension, as the success of the sustainability transition is dependent on the system's ability to reach the "take-off phase" and change its current state (Martens & Rothman, 2005). During the pre-development phase stabilising aspects are still in their early stages. Therefore, abandoning sustainability goals and pathways in the pre-development phase is easy. Strong drivers are required to push the system through these initial regime resistances. Otherwise, the sustainability transition could fail before it impacts the current system state (Schilling *et al*., 2018).

Once the transition starts, the *"take-off phase"* commences, and the *"acceleration phase*" is entered. During the start of the transition, stabilising aspects gain importance because they are the key to keeping the transition on track and preventing any risks, especially during the initial phases of the transition. During the initial phases, a large portion of the system structure has not adapted to the new system state, making the transition vulnerable to unforeseen crises. Therefore, attention must be paid to the "*stabilisation*" of the transition at the beginning of the "*acceleration phase"* (Schilling *et al*., 2018).

In the later stages of the *"acceleration phase"*, the focus should shift towards the *"adaptability"* dimension. When a transition lasts for extended periods, more system structures can change along the current transition pathway, which leads to path dependency. System actors have an easier orientation towards the pathway, but this could lead to a rigid conception of the transition, which results in pathway lock-ins and prevents adaptation towards sustainable development. Therefore, the later stages in the *"acceleration phase"* should focus on the *"adaptability"* of the sustainability transition (Schilling *et al*., 2018).

The final phase of a sustainability transition is the *"stabilisation phase"*, where the system state *"stability"* should be created. Developing system resilience and ending the transition process is pivotal to ensure that the new system state is stabilised and ends the transition process preliminarily. A successful sustainability transition is achieved by shifting the focus of a potential analysis of the transition to the resilience of the new system state. Thus, an RST-based analysis of the *"stabilisation phase"* should focus on system resilience within the *"stability"* dimension (Schilling *et al*., 2018).

TRADE-OFFS WITHIN RST

Interactions between the different dimensions could influence the resilience of a sustainability transition. Achieving a balance between progress, stability, and adaptability by being aware of trade-offs leads to a resilient sustainability transition (Schilling *et al*., 2018). The types of trade-offs within RST are discussed in Table 24 below. Tables 25 to 27 provide current examples of progress, stability, and adaptability in healthcare systems.

Table 24: Trade-offs within the resilience of sustainability transitions (RST) (Schilling *et al*., 2018)

Trade-off	Description
Progress vs Stability	More progress leads to a more efficient process. Radical interventions ensure fast and efficient transitions. Disruptive events can have adverse effects on overall stability. Radical changes can negatively affect the resilience of the system that is in transition. System actors need to react and adapt at the same time. A resilient sustainability transition aims to minimise the adverse effects of disruptive events while ensuring the constant and secure progress of the transition.
Adaptability vs Stability	Ensuring a stable sustainability transition is pivotal to protecting the original vision and idealised transition pathway against disruptive events and disturbances. However, process stability can disrupt the reorientation process of the transition when a new opportunity emerges. Adaption of the sustainability transition can also disrupt the stability of the sustainability transition. A proper balance between stability and adaptability is required to allow for a stable, flexible, and resilient transition process. Transition management activities should focus on stabilising the current state of the sustainability transition while being sensitive to new emerging events.
System Resilience vs Bouncing-Back Risk	Preserving old structures within the system can lower barriers such as cost and effort, which makes it easier to return to a previous state, making this the more attractive alternative if the transition falls short of expectations or in times of high uncertainty. Thus, a bounce-back event results from this scenario if a system returns to a previous system state and reverses the direction of the pathway. The bounce-back risk depends on the cost-benefit ratio of returning to the old system state compared to the expected cost-benefit ratio of continuing the transition. A resilient sustainability transition is as incremental as possible while being disruptive enough to decrease the losses due to the disruptive transitions. That reduces the bouncing back risk without decreasing the resilience of the sustainability transition.

Table 25: Progress in healthcare (adapted from (AGRQ, 2022))

Progress in HC	Drivers for and against progress in HC	**Seek, select, and customise the best evidence for use by the practice**
		Develop a process to search regularly for new evidence.
		Select and customise evidence for practice-wide implementation.
		Embed selected evidence and guidelines into clinical information systems.
		Inform patients and families about the evidence the practice uses and its implications.
		Implement a data-driven quality improvement process to integrate evidence into practice procedures
		Develop an inter-professional improvement team that meets regularly.
		Adopt a consistent quality improvement approach and use quality improvement tools to make changes.
		Select internal quality improvement (QI) measures, collect data, compare with goals and benchmarks, and act on data regularly.
		Engage care teams and other staff to support the implementation of new evidence.
		Optimise health information systems to extract data and support the use of evidence in practice
		Identify and train a data coordinator.
		Use electronic health records to improve data collection.
		Use registries and other data sources creatively to track the provision of evidence-based care.
		Involve care teams in refining documentation workflows to minimise the burden.
		Improve data accuracy and transparency and secure staff trust.
		Link patients to their clinicians and teams within information systems to improve the usefulness of performance reports.
		Create dashboard reports for selected measures.
		Create and support high-functioning care teams to deliver high-quality, evidence-based care
		Establish care teams and delineate team roles for clinical and non-clinical staff.
		Assign patients to clinicians and teams to create accountability and a sense of shared responsibility among the team for their patient panel.
		Team members should be empowered.
		Communication among the care team should be optimised.
		Provide support to the care team in learning about the new evidence.
		Make reviewing their performance and participating in QI activities part of everyone's roles and responsibilities.
		Engage with patients and families in evidence-based care and quality improvement
		Establish workflows that identify and engage patients affected by changing evidence.
		Support patient and family engagement in their evidence-based care.
		Link patients and families with community resources to assist them in implementing evidence-based care plans and meeting their health goals.
		Involve patients and families in moving evidence into practice.
		Nurture leadership and create a culture of continuous learning and evidence-based practice
		Forge a vision of a practice that adapts to a changing evidence environment.
		Provide organisational and leadership support for evidence-based practice and quality improvement.
		Encourage learning about new evidence and best practices.
		Review measures of implementation and impact of evidence-based practices regularly.
		Identify and support champions for learning, evidence-based practice, and quality improvement within the practice.
		Create a culture in which all practice members feel comfortable identifying opportunities for quality improvement.

Table 26: Stability in healthcare (adapted from Rentschler *et al*., 2021)

Stability in HC	**Deal with uncertainty, react to unforeseen events, and recover from shocks in HC**	**Foundations: health systems that can effectively manage routine demand. Ensure universal access to routine healthcare**
		Strengthening managerial and operational capacity, governance, and planning systems
		Strengthening the technical and administrative capacities of the health workforce, including through specialised crisis training
		Improving health information systems for identifying new risks, vulnerabilities, capacity bottlenecks, and information sharing
		Ensuring the availability of essential medical supplies and equipment
		Mobilising and allocating the financial resources needed for routine operations and crisis response
		Resilient health facilities: Ensure adequate capacity and resilience of facilities
		Upgrading structures to withstand shocks and ensure self-sufficiency
		Enhancing staff capacity and training
		Improving facility and inventory management to maximise the utility of limited resources
		Maintaining emergency stocks of essential medical supplies.
		Expanding capacity where possible based on needs (for example, the number of intensive care unit beds)
		Preparing crisis protocols for boosting capacity and ensuring a basic level of care provision (for example, business contingency plans)
		Resilient health systems: Integrate individual health facilities into a coordinated network and improve cooperation during crises
		Using data-driven approaches to identify surge demands early and distribute loads to health facilities and service modalities more effectively.
		Improving communication and cooperation between entities in the health system to manage the surging demand during disasters
		Leveraging solutions for delivering health care services outside health facilities, including community centres, telemedicine, pharmacies
		Deploying mobile clinics to underserved and disaster-hit areas to boost the capacity of permanent health facilities
		Integrated emergency response: Integrate healthcare into disaster risk management (DRM) systems.
		Efficiently meeting wide-ranging critical needs during crises, including food, shelter, security, and healthcare.
		Coordinating with search and rescue agencies such as civil protection and the military to manage health service demand
		Establishing interagency communication channels before disasters strike
		Clearly defining roles and mandates for crisis response to mitigate capacity bottlenecks.
		Enhancing hydrological, meteorological, and early warning services and disseminating information to agencies and the public
		Integrating health system needs in disaster risk finance strategies.
		Resilient infrastructure: Ensure the resilience of critical infrastructure systems on which health facilities depend
		Upgrading transport, water, electricity, and telecommunications assets in critical areas
		Strengthening cyber resilience
		Improving infrastructure maintenance regimes
		Mandating risk-informed infrastructure planning with higher standards for health system-relevant assets
		Leveraging new technologies for service and supply delivery

Table 27: Adaptability in healthcare (adapted from (Valet health, 2022; NIH, 2022))

Adaptability in HC	**Changing boundary conditions and accommodate changes in HC**	**Consumerisation of healthcare**
		Adapt to changes and provide patients with transparency, treatment options, and a care-centred approach.
		Provide educational resources and information about practices and the medical industry.
		Increase in outpatient care
		Medical innovations and the increased need to improve the quality of care and patient outcomes (e.g., telemedicine)
		Lowering healthcare costs while improving patient experiences
		Consolidation of healthcare systems
		Small practices are being targeted by larger systems which are driven by the problematic government reimbursement models, which include lower payment rates and better incentives.
		Consolidation increases healthcare prices due to the lack of general competition.
		Rapidly accelerating consolidation is decreasing the number of available partnerships because small practices are unable to stand up against larger ventures.
		Technological advances in healthcare
		Adapting to a digital mindset for a practice can incur many changes in daily operations and patient interactions.
		Improve patient care and outcomes, streamline physicians' work, and lower costs through digital services and experiences.
		Virtual care is expanding the reach of patients to ensure that patients have easier access to their physicians.

5.2.7 TRANSITION PATHWAYS

According to Geels and Schot (2007) and Geels *et al.* (2016), four transition pathways have been defined by typology. A summary of the four transition pathways is illustrated in Figure 23. This typology is reformulated by transforming it "through the lens of endogenous enactment, identifying the main patterns for actors, formal institutions and technologies" (Geels *et al*., 2016). Berkhout *et al.* (2004) highlighted four ideal types of transformations, which are illustrated in Figure 24.

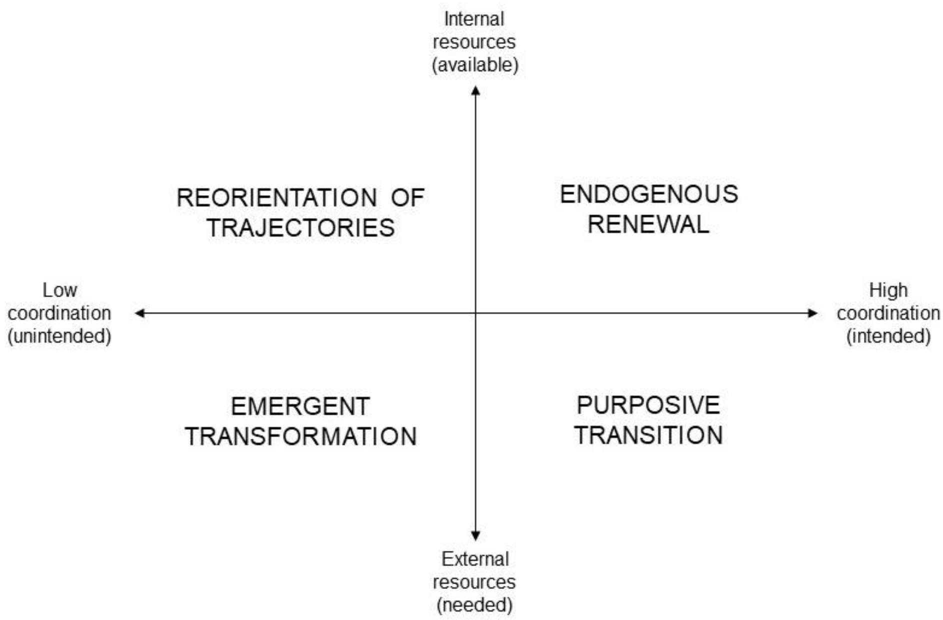


Figure 23: Four transition contexts and transformation processes (adapted from Berkhout *et al*., 2004; De Kock, 2020)

i. Reorientation of trajectories – the responses to the landscape tensions and pressures are formed within the regime, but the stimulation of reorientation is a shock that originates either inside or outside the regime;
ii. Endogenous renewal – the resources required to respond to the pressures are available internally, whilst the change is accommodated at the regime level. The regime actors try to find ways of responding to possible threats to the regime (tension brought upon by the landscape pressures). Innovations are driven from within the regime and thus result in steering the existing regime's values, cognitive structures, and problem-solving abilities. In these instances, the transformations tend to be incremental;
iii. Emergent transformation – these types of transformations develop from unaccommodated pressures, which are for change, and the response depends on resources outside the incumbent regime. These transitions are connected to scientific activities that produce possible solutions to the pressures experienced within the regime. A challenge is, however, to identify which of these identified solutions will be successful and which will not; and
iv. Purposive transitions – emergent transitions have an independent quality. However, purposive transitions are eminent from these since they are intended and pursued to "reflect the expectations of a broad and effective set of interests" (Berkhout *et al*., 2004). Tensions are present in the regime, the actors align their actions with responding to these pressures, and the resources required are unavailable within the regime. Not all purposive transitions contain social and environmental benefits. It is, therefore, essential to highlight the consideration of a broad view of sustainability (considering all aspects and dimensions of sustainability) and considering a systems perspective while considering the impact of the solution on the other elements and actors within a socio-technical system (Berkhout *et al*., 2004).

Socio-technical transitions can be described as an extensive transformation of socio-technical systems that include continuous processes and changes. Socio-technical transitions include "novel" socio-technical designs to establish more sustainable futures (Loorbach, 2014; Markard *et al*., 2012). Socio-technical transitions are purposive transitions associated with the SDGs. They can be defined as "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard *et al*., 2012; Markard *et al*., 2016).

These sustainability transitions have three characteristics, which are:

i. They are goal-seeking and aim to manage societal challenges, which seem to be increasing (Smith et al., 2005);
ii. The alternative of the sustainability transition does not necessarily offer clear benefits to its users compared to the incumbent technologies, which highlights the fact that the transition towards more sustainable socio-technical systems will have to be supported by adaptations in the economic sector of a system (Geels, 2011); and
iii. Incumbent firms, technologies and the provision of complementary assets assist the transition to increased sustainability, which can aid in accelerating and supporting sustainability innovations (Geels, 2011).

Table 28 provides current examples of these transition pathways in healthcare.

	P0	P1			P2	P3		P4
	Reproduction Pathway	**Transformation Pathway**			**De-alignment and re-alignment**	**Technological substitution**		**Reconfiguration Pathway**
		Gradual reorientation of the existing regime through adjustments by incumbent actors in the context of landscape pressures, societal debates, and tightening institutions			The existing regime is disrupted by external shocks, which is followed by the rise of multiple niche innovations and constituencies, some of which gradually becomes dominant.			Niche-innovations and the existing regime combine to transform the system's architecture
Landscape pressure	×	✓			✓	✓		✓
Niche innovation sufficiently developed		×			×	✓		✓
Actors		Incumbents reorient incrementally by adjusting search routines and procedures		Incumbents reorient substantially to radical, new technology, or even more deeply to new beliefs, missions and business models	Incumbents collapse because of landscape pressure, creating opportunities for new entrants	New firms struggle against incumbent firms, leading to overthrow	Various new contestants (e.g., citizens, communities, social movement actors, incumbents from different sectors) replace incumbents	New alliances between incumbents and new entrants
Technologies		Incremental improvements in existing technologies (leading to major performance enhancement over long time periods).	Incorporation of symbiotic niche innovations and add-ons (competence adding, creative accumulation)	Reorientation towards new technologies: (a) partial reorientation (diversification) with incumbents developing both old and new technologies; (b) full reorientation, leading to technological substitution	The decline of old technologies creates space for several innovations which compete with one another	Radical innovation(s) substituting existing technologies		From additional add-ons to new combinations between new and existing technologies; knock-on effects and innovation cascades that change system architecture
Operational changes required		Demonstration of viable alternatives may change perceptions of regime insiders and lead to reorientations of innovative activities.			Multiple niche-innovations that co-exist and compete for attention and resources	Incremental innovations, technology-push character		Substantial changes in the regime's basic architecture, multiple component-innovations
Rules and institutions		Limited institutional change (layering)		Substantial change in institutions (conversion, displacement)	Institutions are disrupted by shocks and replaced, possibly after prolonged uncertainty (Disruption)	Limited institutional changes, implying that niche innovation needs to compete in the existing selection environment also referred to as "fit-and-conform" (incremental adjustment, layering)	Creation of new rules and institutions to niche innovations also referred to as "stretch-and-transform" (disruption, displacement	From limited institutional change (layering) to more substantial change, including operational principles ('drift', 'conversion')

Figure 24: Summary of the different transition pathways (adapted from (De Kock, 2020; Geels & Schot, 2007)

Table 28: Transformation pathways in healthcare (Stephens, 2021; NHS, 2021; NIH, 2002)

Transformation Pathways in HC	Reproduction Pathway
	The regime remains dynamically stable and will reproduce itself if no external landscape tensions are exerted on the existing regime. These dynamics include the competition of firms in markets, the investment of new products being developed, development mutations, and engagement in takeovers. However, these processes occur within a stable regime with rules and proceed within the predicted trajectories. A boost in performance can occur when, over time, accumulated incremental innovations have been implemented.
	Transformation Pathway
	Moderate landscape changes add pressure to the regime, which reorientates the actors of the regime. These landscape changes only apply pressure if the regime actors perceive and act on them.
	Innovative treatments could expand the total addressable market. With the added pressure to improve efficiency and outcomes, deploying patient-centric and integrated care models is pivotal.
	Covid-19 has increased the backlogs and delays in patients' diagnostic and treatment practices, which has increased the search for more digital-first transformation pathways (including remote healthcare and diagnostics).
	Remote monitoring for patients using simple equipment which takes the required readings of the patients, and the patients upload this onto an application along with other personal information such as weight and heart rate. The application, in return, provides the patient with information to adjust their medication and dosages until the best combination is found. This decreases the face-to-face time healthcare professionals need to spend with patients, thus increasing the available resources.
	Societal pressure and social movement groups may protest and demand alternative solutions. Professional scientists or engineers with specialist knowledge may criticise the technical details of the regime and suggest alternative courses of action. External firms, entrepreneurs and activists could develop alternative practices or technologies.
	High-volume specialities with established digital pathways offer choices to patients and ensure that healthcare professionals can concentrate their time and resources on patients with more severe and complex medical conditions. Long-term and complex conditions will be monitored using digital platforms and medical devices with adequate data flow between the clinical system, which is supported by technical standards, which will ensure that the clinical teams have the data to make informed decisions.
	De-alignment and Realignment Pathway
	Landscape pressures are divergent, large, and sudden, resulting from lost faith in the current regime. Eventually, a niche innovation becomes dominant as multiple niche innovations compete, forming the core for re-aligning a new regime. With no stable niche innovation to fill the gap, the "vacuum" leads to the development of multiple embryonic niche innovations, which outsiders and diverse regime actors carry.
	Policies aimed at encouraging entrepreneurial start-ups which create business value (like medical and wellness apps) might end up being suboptimal innovations and solutions in creating a cluster of social value.
	Innovative surgical devices, treatment methods, imaging equipment, and apps are adopted and used in spread-out arrangements. At the same time, the clinical benefits and added value for the costs it incurs to the healthcare system remain understudied. The current regulations and policies for introducing innovation at an in-hospital or digital technologies level are often not substantiated by the evidence of cost-effectiveness.
	The open-ended implementation of predictive AI, hybrid operation rooms, gene editing, etc., which leads a route from the innovative promises to create actual value, is complex and dependent on infrastructure, training, user experience, safety and privacy protocols, liability, business models, and maintenance.
	The new diagnosis and therapy technology distribution can contribute to increased patient demands, health anxiety, over-treatment, and medicalisation. This highlights the need for ethical suitability of how innovation shapes the provision of social service delivery, the definition of human diseases, and patterns of allocation of resources in healthcare systems, which is often unclear and understudied.
	Medical innovations give rise to problems regarding the affordability of well-developed and developing healthcare systems. It increases expenditure growth as it is responsible (on average) for half of the annual increase experienced in healthcare costs. Concerns regarding affordability and access can harm the societal support for maintaining these healthcare systems, resulting in instability in social solidarity.

Transformation Pathways in HC	**Technological Substitution Pathway**
	A connected ecosystem containing sensors and devices on and around individuals serves the healthcare functions of capturing and measuring, identifying, stratifying risks, informing, decision-making, and acting. Technologies include AI, robotic care, nanorobots, cyborgisation, Brain-Computer Interfaces, Medical Tricorders (diagnostic devices), digital avatars, virtual reality, 3D Printing, etc.
	Remote monitoring for patients using simple equipment which takes the required readings of the patients, and the patients upload this onto an application along with other personal information such as weight and heart rate. The application provides the patient with information to adjust their medication and dosages until the best combination is found. This drastically decreases the face-to-face time healthcare professionals need to spend with patients, thus increasing the available resources.
	High-volume specialities with established digital pathways offer choices to patients and ensure that healthcare professionals can concentrate their time and resources on patients with more severe and complex medical conditions. Long-term and complex conditions will be monitored using digital platforms and medical devices. Adequate data flow between the clinical system, supported by technical standards, will ensure that the clinical teams have the data to make informed decisions.
	Reconfiguration Pathway
	Healthcare systems need to balance two primary purposes: responding to the population's demands to gain access to the existing healthcare services and improving the whole population's health (decreasing the waiting list and improving coronary health status in the longer term, for example). There need to be more explicit investment frameworks for healthcare gain, discussions are dominated by the buildings and not the systems, employment patterns and pay policies are underused as actors for change, and there is a bias towards centralisation. These highlight opportunities for reconfiguration in healthcare systems by managing clinical networks, virtuality and knowledge technologies, easy access to capital and increasing revenues, and recognising that human resource problems are a design issue in healthcare systems.

5.3 CHAPTER 5: CONCLUSION

In this chapter, the third phase in the systems engineering process, namely the functional analysis, was conducted. The functional analysis aims to identify intervention strategies that would address the requirement specifications. This led to the proposition of the LT4ST index in the next chapter. The author identified which lean thinking principles or approaches are deemed applicable in healthcare systems (as a socio-technical system) and then synthesised them into an index with the transition approaches as discussed in this chapter. These lean thinking principles and approaches are deemed appropriate intervention strategies to support sustainability transitions in healthcare. The integration strategy, which details the research products' development process, is also presented. A framework, methodology, and index are to be developed to contribute towards the implementation of lean thinking to support sustainability transitions in healthcare. The framework, methodology, and index's requirement specifications and the development process have been presented and will, in conjunction with systems engineering and industrial engineering principles for systems thinking, aid as a guide in developing the framework in the next chapter.

CHAPTER 6: THE LEAN THINKING FOR SUSTAINABILITY TRANSITIONS IN HEALTHCARE INDEX, FRAMEWORK & METHODOLOGY

The design synthesis phase, the final phase of the systems engineering approach, integrates the findings from the preceding phases and is illustrated in Figure 25 below. These phases are (i) the input identification phase (Chapters 2 & 3), (ii) the requirement analysis phase (Chapter 4), and (iii) the functional analysis phase (Chapter 5). The design synthesis phase is the process that includes the definition and development of functional products that can be utilised to address the research problem (United States Government, 2001). The literature analysis highlighted that implementing lean thinking approaches and principles to support sustainability transitions in healthcare is limited. Therefore, this research aimed to develop (i) an index to identify and define the role of lean in sustainability transitions that indicates which lean thinking approach or principle addresses which sustainability transition, (ii) a framework, and (iii) the operationalisation strategy of the LT4STHC framework. This framework is titled the Lean Thinking for Sustainability Transitions in Healthcare (LT4STHC). In this chapter, the purpose of the LT4STHC framework, an overview of the LT4STHC framework and the approach used to develop the framework will be discussed.

Therefore, this research aimed to develop (i) the LT4ST index that indicates which lean thinking approach or principle supports which sustainability transition, (ii) a framework, and (iii) the methodology of the framework. The development of the index, framework and methodology is presented to fulfil the RO4 (refer to Section 1.3).

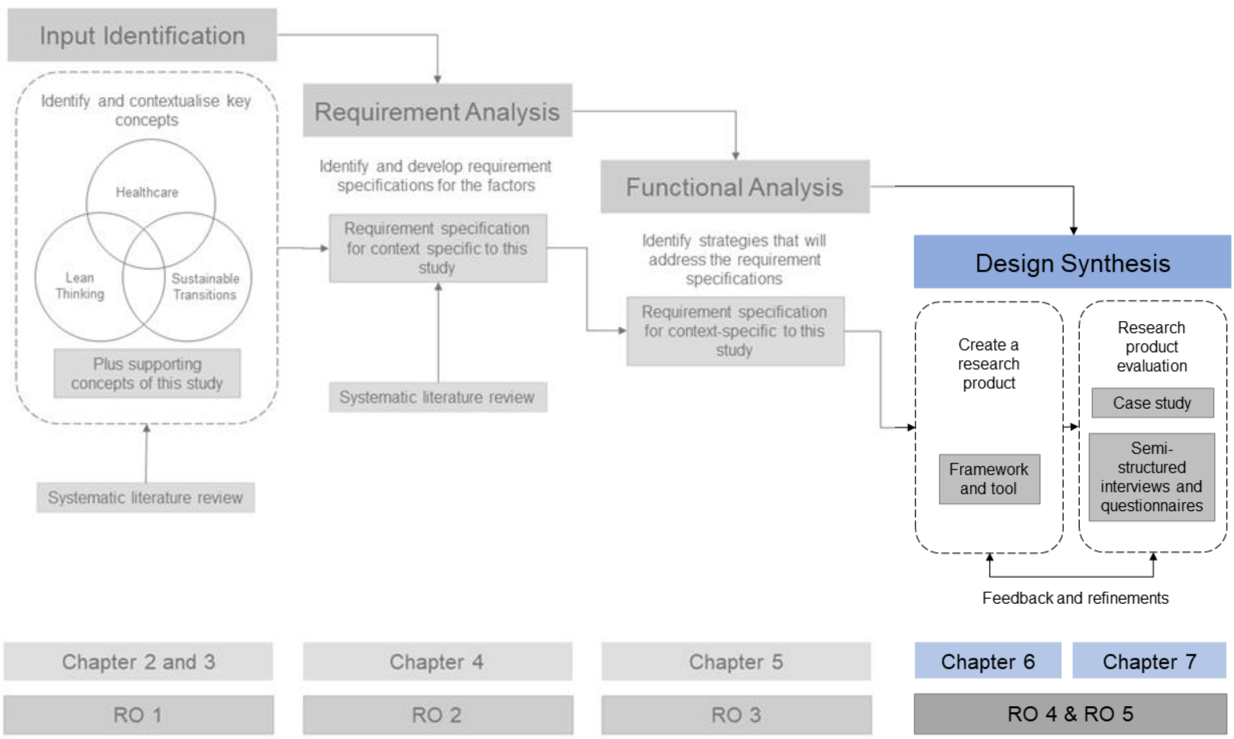


Figure 25: Design synthesis, research products development of an adapted systems engineering approach

6.1 LT4STHC FRAMEWORK PURPOSE

To identify which lean thinking approach or principle could be implemented to support specific aspects, occurrences, or phases in sustainability transitions in healthcare, the LT4ST was developed. The LT4ST index is accompanied by the LT4STHC framework, which is a visual presentation of the LT4ST index. Subsequently, as outlined in this chapter, the developed framework is translated into a methodology. The LT4STHC methodology provides a practical approach to determine which lean thinking approaches or principles could be used to support and facilitate sustainability transitions in healthcare. The methodology is aimed at developing a customised implementation strategy for healthcare systems. The methodology provides a guide on addressing the implementation of lean thinking to support sustainability transitions in healthcare by identifying intervention strategies that are the most appropriate. The development of the framework builds on the discussions that have been presented in the preceding chapters. In Chapter 3, the knowledge gap about lean implementation in sustainability transitions in healthcare was identified. To address this gap and resultantly guide the development of the methodology, requirement specifications were identified in Section 4.2. As presented in Chapter 5, the intervention strategy analysis of socio-technical transitions has been identified as a key consideration for analysing contemporary global systems in transitions to more sustainable states. It was also identified that lean thinking approaches and principles are synonymous with sustainability, and both concepts have implications for sustainability and sustainable development within contemporary global systems. The development of a framework will facilitate an understanding of how lean thinking can support sustainability transitions in healthcare. Lean thinking and sustainability transitions also pertain to global systems and can contribute towards an in-depth understanding, orientation and implication for global sustainability and sustainable development (Chapters 1 and 2).

6.2 LT4STHC FRAMEWORK DEVELOPMENT APPROACH

This study will employ Van Aken *et al*. (2007)'s model as the methodology for the development of the framework, as illustrated in Figure 26. This model for the design process management is a stepwise process model that describes the process of developing an intended object (i.e., a framework), as it is broken down into sub-steps. At the same time, the action in each step is controlled by process management. These steps do not follow a fixed sequential occurrence in the development of the framework. However, it is conducted iteratively to explore the steps and modify the framework as needed. This ensures that the development process is flexible and agile (Van Aken *et al*., 2007).

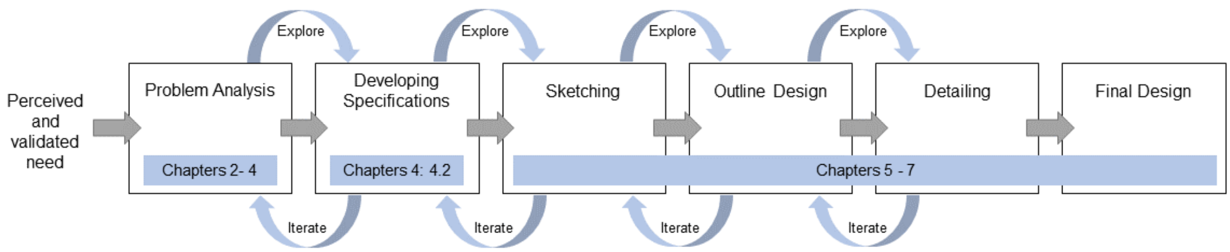


Figure 26: General model for a development process (Process Management) (Van Aken *et al*., 2007)

The process commences with the perceived and validated needs as its input. The perceived and validated needs have been detailed in this research's previous chapters (Chapters 1 and 3). The problem analysis, the subsequent step in process management, is elaborated in chapters 2 to 4 of this study. The next step of developing the specifications is described in Section 4.2.

Using Van Aken *et al.* (2007)'s methodology to develop a framework, the identified requirement specifications (refer to Section 4.2) and literature (refer to Chapter 5) have been used as the basis for developing the LT4STHC framework, as discussed in Table 29.

The identified features that will be incorporated into the LT4STHC framework used to fulfil the requirement specifications are:

i. LT4ST index is a visual representation of the synthesised index. This instrument is used as a visual aid to determine which lean thinking approaches or principles could support the respective sustainability transitions;
ii. MLP, ISA, TM, which is used to approach sustainability transitions from a socio-technical perspective as these are identified analysis approaches to understand socio-technical transitions better;
iii. Lean4… tables are presented (refer to Appendix C), which indicate which lean thinking approach or principle could support the occurrence of landscape tensions, regime stress, niche pressure, the lack of progress, the lack of stability, the lack of adaptability, system weaknesses, transition and transformational failures, the introduction of new sustainable technology, and various transition pathways;
iv. The LT4STHC framework and methodology are presented, which applies to socio-technical systems, specifically healthcare; and
v. A case study application is presented, which indicates the understandability, unambiguity, clarity, conciseness, practicability, applicability, and usability of the LT4STHC framework and methodology.

Table 29: Requirement specifications and correlating features of the LT4STHC framework

Requirement Specification ID	**Features of the LT4STHC framework and methodology**
Functional Requirements	
FR1: The research products should sufficiently integrate lean thinking into sustainability transitions in healthcare.	LT4ST index
FR2: The research products should approach sustainability transitions from a socio-technical transition perspective.	MLP, ISA, TM
FR3: The research products should incorporate an understanding of lean thinking in healthcare within a holistic context.	Lean thinking approaches and principles have been identified that could be used during various phases and occurrences of a sustainability transition. (1) Lean4Tension, (2) Lean4Stress, (3) Lean4Pressure, (4) Lean4Progress, (5) Lean4Stability, (6) Lean4Adaptability, (7) Lean4Weaknesses, (8) Lean4Failures, (9) Lean4SNM, and (10) Lean4Pathways.
FR4: The research products should apply to socio-technical systems.	The LT4STHC framework methodology is developed in such a manner that it can be used by any socio-technical system, specifically healthcare.
User Requirements	
UR1: The research products should be understandable and unambiguous.	The case study indicates the level of understandability, unambiguity, clarity, and conciseness of the LT4STHC framework and the methodology.

Requirement Specification ID	Features of the LT4STHC framework and methodology
UR2: The research products should be clear and concise.	The case study is also presented as a practical implementation example.
UR3: The research products should provide clear definitions and explanations to cater to a broad range of levels of experience in lean, sustainability transitions, and healthcare.	
UR4: The research products should be accompanied by practical implementation strategies a utility because it is developed from an engineering perspective.	

Sketching, outline design and detailing regarding the iterative and explorative development of the framework follows the problem analysis phase. Sketching is informal and not presented in this document, but it serves as a pivotal step in the formulation of the initial ideas of the framework. The outline design step presents a more detailed and formalised product and details decisions that consider key development dilemmas (Van Aken *et al*., 2007). The outline design step of Van Aken *et al.* (2007) is presented in Section 6.3 utilising the author's developed LT4ST index. The detailing step, presented in Section 6.4, entails detailing the LT4STHC framework, which is a visual presentation of the LT4ST index. The final step of Van Aken *et al.* (2007)'s process management method is the final design, which is presented in Sections 6.5 and 6.6. The final design for the implementation of lean thinking to support sustainability transitions in healthcare is presented as an operationalisation strategy and methodology of the LT4STHC framework.

6.3 LT4ST INDEX DEVELOPMENT

The LT4ST index, as illustrated in Figure 28, is the role of lean thinking in sustainability transition approaches. This step was conducted by analysing Chapter 5, approaches for transitional change in healthcare, to determine which identified lean thinking approach or principle implemented successfully in healthcare, as mentioned in Sections 2.2 and 3.4, and could support the

i. Forces and Conditions for Transitional Change (landscape tensions, regime stresses, and niche pressures in healthcare) as identified and discussed in Section 5.2.1;
ii. Transitional and Transformational failures (Lock-ins, System breakdown, Backlash, Directionality failure, demand articulation failure, policy coordination failures, reflexivity failures occurring in healthcare) as identified and discussed in Section 5.2.2;
iii. Innovation System Approach (TIS), as identified and discussed in Section 5.2.3;
iv. SNM as identified and discussed in Section 5.2.4;
v. RST (progress, stability, and adaptability in healthcare) as identified and discussed in Section 5.2.6; and
vi. Transition pathways (transformation pathway, de-alignment and re-alignment pathway, technological substitution, reconfiguration pathway in healthcare) as identified and discussed in Section 5.2.7.

Lean management is a broad concept that covers a wide range of evidence-based practices (i.e., team mental models, goal setting, effective communication, transformational and complexity leadership). Thus, lean implementation has no single manner or organisational level where it can be implemented. Lean management has an empirical basis which means that lean is a holistic concept that can be considered as having a positive impact on various organisational levels if implemented correctly (Nini, 2020). According to Sarkar (2009), lean in a service can be defined in two ways:

"*Lean is an improvement philosophy that targets to improve the performance of a business system by focusing on elements that do not add value. It is about creating an agile engine, which helps an organisation weather the storm of competition"* (Sarkar, 2009).

And,

"Lean is a process optimisation methodology that focuses on improving the effectiveness and efficiency of a process by eliminating activities that do not add value to the customers and the product. It manifests itself in reducing cycle time, touch time, and lead time" (Sarkar, 2009).

Several approaches have been considered to determine the extent to which the respective lean thinking approaches and principles, successfully implemented in healthcare, can contribute to supporting sustainability transitions in healthcare. These approaches include:

i. Strategic, Tactical, Operational, and Reflexive Operational Level Analysis (Transition Management), which involves determining at which organisational level the lean thinking approaches and principles could be implemented;
ii. MICMAC analysis, which involves the development of a graph that classifies the respective lean thinking approaches or principles based on their driving and dependence power in a sustainability transition;
iii. Interpretive Structural Modeling (ISM) analysis, which involves identifying the relationship between the respective lean thinking approach or principle and the sustainability transition;
iv. Descriptive, Predictive, Prescriptive, and Diagnostic Analysis, which involves determining how the lean thinking approach or principle could contribute to the sustainability transition; and
v. Regression Analysis, which involves determining the relationship between a set of variables, in this case, lean thinking approaches and principles in relation to sustainability transitions.

The aim is to determine at which organisational level in the healthcare system the respective lean thinking approaches or principles can be implemented, and how they can be implemented to determine what happened, why it happened, what could happen, and what should happen. Thus, the lean thinking approaches or principles will be stipulated against strategic, tactical, operational, and reflexive operational levels, and descriptive, predictive, prescriptive, and diagnostic analytical perspectives.

Transition management (Elzen *et al*., 2004), further detailed by integrating several analytical perspectives, has been selected to conduct the analysis to understand "*at which system level"* the identified lean thinking approaches and principles can contribute towards supporting sustainability transitions in healthcare. Transition Management is selected to understand at which level in the system (strategic, operational, tactical, or reflexive) the identified lean thinking approach or principle can contribute towards supporting the sustainability transition in healthcare. The analytical perspectives are selected to understand to which extent (descriptive, predictive, prescriptive, or diagnostic) the identified lean thinking approach or principle can contribute to supporting sustainability transitions in healthcare. These approaches have been selected because the aim is to identify where and how the identified lean thinking approaches and principles in the healthcare system could contribute towards supporting sustainability transitions in healthcare.

Transition Management, as identified and discussed in Section 5.2.5, is then used to determine at what system level the lean thinking approaches or principles could support sustainability transitions in healthcare, namely:

i. Strategic level (**TMS**);
ii. Tactical level (**TMT**);
iii. Operational level (**TMO**); and
iv. Reflexive level (**TMR**).

Four analytical perspectives (InsightSoftware, 2021), which will indicate the extent to which the lean thinking approaches and principles could support sustainability transitions in healthcare, were considered. These perspectives are:

i. Descriptive analytical perspective (**APDS**), which pertains to understanding what has happened;
ii. Predictive analytical perspective (**APPD**), which pertains to understanding what could happen in the future based on previous trends or patterns;
iii. Prescriptive analytical perspective (**APPS**), which pertains to understanding what the system should do moving forward; and
iv. Diagnostic analytical perspective (**APDN**), which pertains to understanding why what happened.

Each lean thinking approach or principle was classified and assigned according to these two analytical approaches. The approach is graphically illustrated in Figure 27 below.

The first step was to determine whether the lean thinking approach or principle could contribute to supporting the sustainability transition approach. A tick mark was allocated to the respective sustainability transition where the lean thinking approach or principle was deemed applicable in addressing the sustainability transition. If the lean thinking approach is deemed viable to address the sustainability transition, it was further determined how the lean thinking approach or principle could contribute to support the progression of the sustainability transition. The viability of the lean thinking approach or principle to support the sustainability transition was determined based on the definition of the respective lean thinking approaches and principles. The goal of the lean thinking approach or principle was the determining factor in determining whether the lean thinking approach or principle could support the progression of the sustainability transition.

The second step entailed determining in which way the individual lean thinking approach or principle could contribute toward supporting the progression of the sustainability transition. The strategic level implies that the lean thinking approach or principle could assist in achieving sustainable visions and the purpose of a sustainable business model at a large scale. The lean thinking approach or principle should be applied to change dominant cultures and practices to the societal level of the system. A tactical level implies that the lean thinking approach or principle could assist in achieving a set of networks and collaborations toward sustainability with key stakeholders identified in a sustainable business model. The lean thinking approach or principle should be applied to change the dominant operational structure of value creation along the value chain at the sectoral level. The operational level implies that the lean thinking approach or principle could assist in establishing a sustainable business model vision and purpose and start implementing sustainable-related practices. The lean thinking approach or principle should be applied to change dominant practices at a firm level. The reflexive level implies that the lean thinking approach or principle could assist in monitoring or evaluating the current situation at the strategic, tactical, and operational levels, as well as the interrelation or misfit.

Different analytical perspectives were also considered to determine the manner in which the respective lean thinking approach or principle could assist in supporting the progression of the sustainability transition in healthcare. The descriptive analytical perspective implies that the lean thinking approach or principle could assist in determining "what happened?" in the sustainability transition or healthcare system. The predictive analytical perspective implies that the lean thinking approach or principle could assist in determining "what could happen?" in the sustainability transition or healthcare system. The prescriptive analytical perspective implies that the lean thinking approach or principle could assist in determining "what should happen?" in the sustainability transition or healthcare system. The diagnostic analytical perspective implies that the lean thinking approach or principle could assist in determining "why did it happen?" in the sustainability transition or healthcare system. The different analytical approaches were allocated to the respective lean thinking approach or principle based on their definitions and goals in healthcare, as stated by the literature.

The final step was allocating a tick mark and the respective analytical methods to the lean thinking approach or principle that could support the progression of the sustainability transition in healthcare.

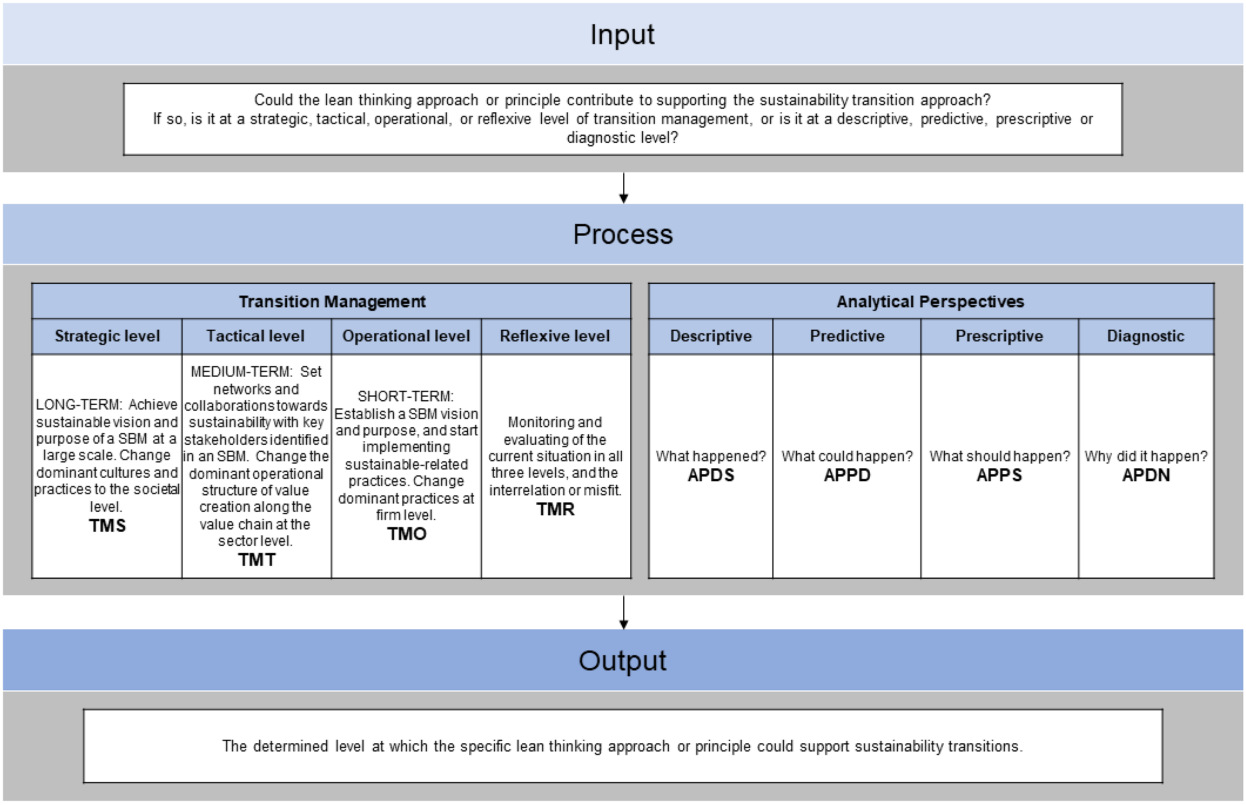


Figure 27: Tool used to determine at which system level and to which extent lean thinking can support sustainability transition

The LT4ST index, as illustrated in Figure 28, is a representation of the role of lean in sustainability transitions in healthcare. The viability of the lean thinking approach was determined based on the definition of the respective lean thinking approaches and principles as well as the use of the implementation in existing examples. These existing examples comprised of literature resources that indicates the successful use of the specific lean thinking principle in similar scenarios. The LT4ST index indicates which respective lean thinking approach or principle, successfully implemented, could support the progression of sustainability transitions in healthcare. LT4ST index is integrated into the LT4STHC framework, which is developed in Chapter 6.

				Approaches for Transitional Change in Healthcare																			At what organisational level and how the lean thinking approach or principle can contribute							
				Forces for Change			The Resilience of Sustainability Transitions			Transition Failures (7. Lean4Failures)							Innovation System Approach (8. Lean4Weaknesses)	Strategic Niche Management (9. Lean4SNM)	Transition Pathways (10. Lean4Pathways)											
				Landscape Tension (1. Lean4Tension)	Regime Stress (2. Lean4Stress)	Niche Pressure (3. Lean4Pressure)	Progress (4. Lean4Progress)	Stability (5. Lean4Stability)	Adaptability (6. Lean4Adaptability)	Lock-ins	System breakdown	Backlash	Directionality failure	Demand articulation failures	Policy coordination failures	Reflexivity failures			Transformation pathway	De-alignment and re-alignment pathway	Technological substitution	Re-configuration pathway	Strategic Level	Tactical Level	Operational Level	Reflexive Level	Descriptive	Predictive	Prescriptive	Diagnostic
Lean Thinking	4P Model of the Toyota Way & Liker's Lean	Problem Solving - continuous improvement & learning	Continuous organisational learning through **Kaizen** (continuous improvement, letting the workers think in solutions)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			Genchi Genbutsu: physically going to and observing a location (and its conditions) to understand and solve problems faster and more effectively	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
			Slow decision-making by consensus, considering all options (rapid implementation)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		People & Partners - respect, challenge and grow	**Grow leaders** who live the lean philosophy	✓	✓	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
			Respect, develop, challenge **people and team**	✓	✓	✓	✓	✓	✓	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×
			Respect, challenge and help **suppliers**	✓	✓	✓	✓	✓	✓	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	×	×	×
		Process - Eliminate waste	Create process **flow**	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	×	×	✓	×
			Use **pull system** to avoid overproduction	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×	✓	✓	✓	×	×	✓	×
			Heijunka : level out the workload	×	✓	×	✓	✓	×	×	×	×	×	×	×	×	✓	✓	✓	×	✓	×	×	✓	✓	✓	×	×	✓	×
			Jidoka : stop when there is a quality problem; automation with a human touch, to help workers in their daily labors	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×	✓	×	×	✓	✓	✓	×	✓	✓
			Standardize tasks for quality improvement	✓	✓	×	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×	✓	✓	✓	✓	×	×	✓	×
		Philosophy - long term thinking	Base management decisions on **long-term philosophy** (even at expense of short-term financial goals)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×

			Approaches for Transitional Change in Healthcare																			At what organisational level and how the lean thinking approach or principle can contribute							
			Forces for Change			The Resilience of Sustainability Transitions			Transition Failures (7. Lean4Failures)							Innovation System Approach (8. Lean4Weaknesses)	Strategic Niche Management (9. Lean4SNM)	Transition Pathways (10. Lean4Pathways)				Strategic Level	Tactical Level	Operational Level	Reflexive Level	Descriptive	Predictive	Prescriptive	Diagnostic
			Landscape Tension (1. Lean4Tension)	Regime Stress (2. Lean4Stress)	Niche Pressure (3. Lean4Pressure)	Progress (4. Lean4Progress)	Stability (5. Lean4Stability)	Adaptability (6. Lean4Adaptability)	Lock-ins	System breakdown	Backlash	Directionality failure	Demand articulation failures	Policy coordination failures	Reflexivity failures			Transformation pathway	De-alignment and re-alignment pathway	Technological substitution	Re-configuration pathway								
Lean Thinking	Lean Practices & Approaches	**Mindset and attitude:** understand and communicate; ensure that cogninitive dimension, tools and concepts are learned	✓	✓	✓	✓	✓	✓	×	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lean Thinking	Lean Practices & Approaches	**Leadership and management:** in-depth understanding of lean journey to manifest a lean culture; skilled people are used in the right place	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lean Thinking	Lean Practices & Approaches	**Employee involvement:** ensure willingness to change; employee development (human capital)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lean Thinking	Lean Practices & Approaches	**Tools and techniques: 5S** (It is a discipline to increase productivity with the standardization of cleanliness and organization habits) ,**VSM** (is the identification of all the operations in the company, showing the value and non value ones), **Bottleneck Analysis**, **Overall Equipment Effectiveness**, **Plan-Do-Check-Act**, **Error Proofing**, **Root Cause Analysis**, **SQDC** (Safety, Quality, Delivery, Cost), **A3 Lean Thinking Process**, **Waste Observation Chart**, **Process Flow Map**, **Change management plan**, **Poka Yoke** (mistake proofing), **Hoshin Kanry** (This technique define all the company objectives under Lean principles), **Kanban** (mechanism to flow control and production control, letting produce only what is needed in the moment when it is needed and in the quantity needed), **Andon** (visual signal to inform when something is wrong or is in an abnormal condition), **SMED** (created by Shingo, reduce the set up times - complete as many steps as possible while the equipment is running (or processing), so as to save time and quickly change-over to processing the next product)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
Lean Thinking	Lean Practices & Approaches	**Six Sigma:** reduce the occurance of defects in products/services; speeds up deliveries, reduces costs, increase quality	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×

					Approaches for Transitional Change in Healthcare																				At what organisational level and how the lean thinking approach or principle can contribute							
					Forces for Change			The Resilience of Sustainability Transitions			Transition Failures (7. Lean4Failures)							Innovation System Approach (8. Lean4Weaknesses)	Strategic Niche Management (9. Lean4SNM)	Transition Pathways (10. Lean4Pathways)												
					Landscape Tension (1. Lean4Tension)	Regime Stress (2. Lean4Stress)	Niche Pressure (3. Lean4Pressure)	Progress (4. Lean4Progress)	Stability (5. Lean4Stability)	Adaptability (6. Lean4Adaptability)	Lock-ins	System breakdown	Backlash	Directionality failure	Demand articulation failures	Policy coordination failures	Reflexivity failures			Transformation pathway	De-alignment and re-alignment pathway	Technological substitution	Re-configuration pathway		Strategic Level	Tactical Level	Operational Level	Reflexive Level	Descriptive	Predictive	Prescriptive	Diagnostic
Lean Thinking	Lean Principles	L1	Reducing/Eliminating activities that do not add value	S1: Reduce resources S10: Increase capacity of reuse, remanufacture and recondition	✓	✓	✓	✓	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×
		L2	Reducing uncertainty	S1: Reduce resources S2: Time efficiency S11: Reduce energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×
		L3	Focus on customer requirements	S2: Time efficiency S3: Reduce waiting time S6: Support community activities	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×
		L4	Reduce cycle time	S1: Reduce resources S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×
		L5	Simplifying the process	S3: Reduce waiting time S9: Increase recycling capacity S11: Reduce energy consumption S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	×	✓	×	×	✓	×	✓	✓	×	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×
		L6	Increase production flexibility	S9: Increase recycling capacity S10: Increase capacity of reuse, remanufacture and recondition S11: Reduce energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×
		L7	Increase process transparency	S1: Reduce resources S2: Time efficiency S11: Reduce energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	×	×	✓	×

Lean Thinking – Lean Principles		Sustainability	Approaches for Transitional Change in Healthcare – Forces for Change: Landscape Tension (1. Lean4Tension)	Forces for Change: Regime Stress (2. Lean4Stress)	Forces for Change: Niche Pressure (3. Lean4Pressure)	The Resilience of Sustainability Transitions: Progress (4. Lean4Progress)	The Resilience of Sustainability Transitions: Stability (5. Lean4Stability)	The Resilience of Sustainability Transitions: Adaptability (6. Lean4Adaptability)	Transition Failures (7. Lean4Failures): Lock-ins	Transition Failures: System breakdown	Transition Failures: Backlash	Transition Failures: Directionality failure	Transition Failures: Demand articulation failures	Transition Failures: Policy coordination failures	Transition Failures: Reflexivity failures	Innovation System Approach (8. Lean4Weaknesses)	Strategic Niche Management (9. Lean4SNM)	Transition Pathways (10. Lean4Pathways): Transformation pathway	Transition Pathways: De-alignment and re-alignment pathway	Transition Pathways: Technological substitution	Transition Pathways: Re-configuration pathway	At what organisational level and how the lean thinking approach or principle can contribute: Strategic Level	Tactical Level	Operational Level	Reflexive Level	Descriptive	Predictive	Prescriptive	Diagnostic
L8	Controlling the entire process	S7: Train human resources S10: Increase capacity of reuse, remanufacture and recondition S11: Reduce energy consumption S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×
L9	Improving the process continuously	S1: Reduce resources S4: Monitor fixed cost S9: Increase recycling capacity S11: Reduce energy consumption S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×
L10	Gathering information about competitors	S5: Stakeholder involvement in strategic decisions	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
L11	Reduction of raw materials	S1: Reduce resources S4: Monitor fixed cost S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×
L12	Efficient allocation of human resources	S1: Reduce resources S5: Stakeholder involvement in strategic decisions S6: Support community activities S7: Train human resources S8: Corporate Social Responsibility (CSR)	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	×	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×

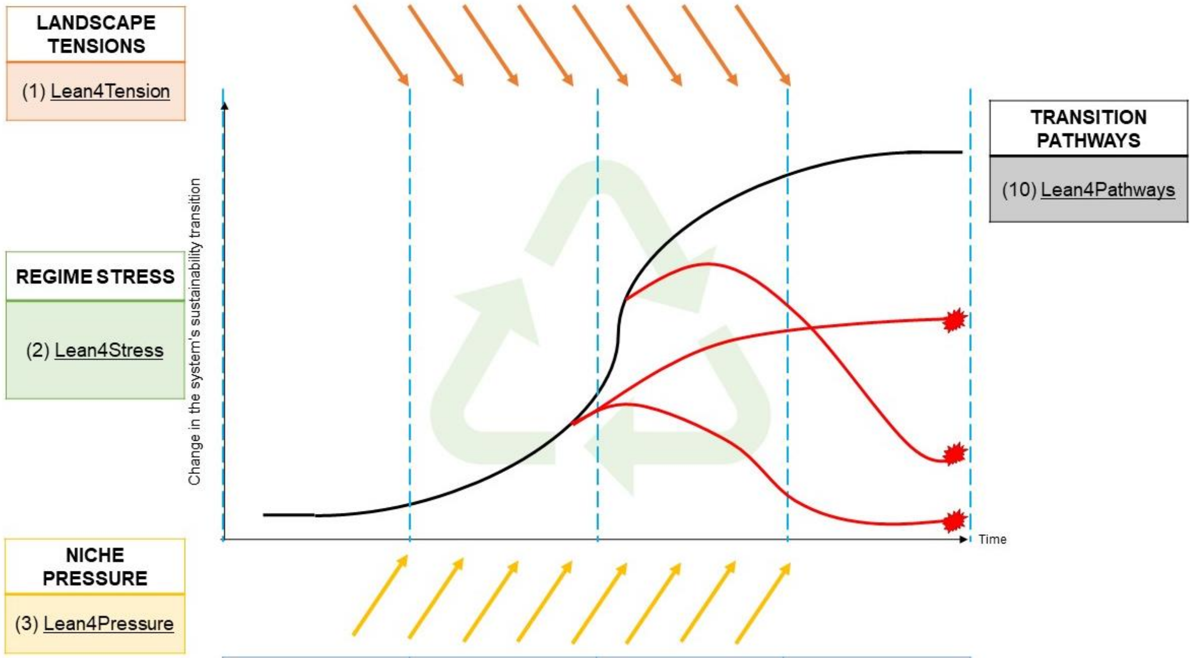
Figure 28: LT4ST index – “The role of lean in sustainability transitions in healthcare systems”

6.4 LT4STHC FRAMEWORK ABSTRACTION

The LT4STHC framework, as illustrated in Figure 29, is a visualisation of the implementation of the LT4ST index (refer to Figure 28 in Section 6.3). Using the various approaches to understand aspects of sustainability transitions (refer to Section 5.2), ten "*Lean4…*" combinations have been identified and placed in their respective areas/scenarios of implementation. The identified combination of lean thinking approaches and principles (in Appendix B) could be used to support the progression of the sustainability transition during the transition process. These ten combinations are illustrated in Table 30.

Table 30: Lean for sustainability transitions

Transition Approaches	Lean4…	Description	Table reference
Landscape tension	(1) Lean4Tension	Lean thinking approaches and principles that could aid in addressing the occurrence of landscape tensions in sustainability transitions.	Table 49 in Appendix B
Regime stress	(2) Lean4Stress	Lean thinking approaches and principles that could aid in addressing the occurrence of regime stresses in sustainability transitions.	Table 50 in Appendix B
Niche pressure	(3) Lean4Pressure	Lean thinking approaches and principles that could aid in addressing the occurrence of niche pressures in sustainability transitions.	Table 51 in Appendix B
Progress	(4) Lean4Progress	Lean thinking approaches and principles that could aid in addressing the lack of progress support in sustainability transitions.	Table 52 in Appendix B
Stability	(5) Lean4Stability	Lean thinking approaches and principles that could aid in addressing the lack of stability in sustainability transitions.	Table 53 in Appendix B
Adaptability	(6) Lean4Adaptability	Lean thinking approaches and principles that could aid in addressing the lack of adaptability in sustainability transitions.	Table 54 in Appendix B
Transition and transformational failures	(7) Lean4Failures	Lean thinking approaches and principles that could aid in guarding against the occurrence of transition and transformational failures in sustainability transitions.	Table 55 in Appendix B
Innovation System Approach	(8) Lean4Weaknesses	Lean thinking approaches and principles that could aid in guarding against the presence of a system weakness in sustainability transitions.	Table 56 in Appendix B
Strategic Niche Management	(9) Lean4SNM	Lean thinking approaches and principles that could aid in supporting the emergence and introduction of a technology niche in sustainability transitions.	Table 57 in Appendix B
Transition pathways	(10) Lean4Pathways	Lean thinking approaches and principles that could aid in supporting different transition pathways in sustainability transitions.	Table 58 in Appendix B



PRE-DEVELOPMENT PHASE	TAKE-OFF PHASE	ACCELERATION PHASE	STABILIZATION PHASE
(4) Lean4Progress (pay **close** attention to progress) (5) Lean4Stability (pay attention to stability)	(5) Lean4Stability (pay **close** attention to stability) (4) Lean4Progress (pay attention to stability) (6) Lean4Adaptability (pay **some** attention to adaptability)	(6) Lean4Adaptability (pay **close** attention to stability) (5) Lean4Stability (pay attention to stability) (4) Lean4Progress (pay **some** attention to progress)	(5) Lean4Stability (pay **close** attention to stability) (6) Lean4Adaptability (pay attention to stability)
Strong drivers required to push the system through initial regime resistances, otherwise sustainability transition could fail before it has an impact on current system state (9) Lean4SNM	Keep the transition on track and prevent any risks, especially during the beginning phases: (7) Lean4Failures & (8) Lean4Weaknesses	Keep the transition flexible as more system structures get the opportunity to change along the current transition pathway (which could cause lock-ins, backlash, or system breakdowns, and other failures due to a lack of adaptability): (7) Lean4Failures	Develop system resilience and end the transition process to ensure that the new system state is stable.

Figure 29: LT4STHC framework

6.5 OPERATIONALISATION OF THE LT4STHC FRAMEWORK: A METHODOLOGY

In this section, the development of the LT4STHC methodology is outlined. The methodology essentially constitutes the operationalisation of the LT4STHC framework to ensure practical utility of the developed framework. The methodology aims to guide the users to, penultimately and ultimately identify applicable aims to implement lean thinking approaches and principles to support the progression of sustainability transitions in healthcare systems.

The LT4STHC methodology consists of four phases. Phase 1 involves investigating and analysing the sustainability transition in the healthcare system (as a socio-technical system). The second phase pertains to identifying the aspect or phase in the sustainability transition that requires support for the sustainability transitions to move on to the next phase. Phase 3 relates to identifying which lean thinking approach or principle could be used to address the identified aspect or phase in the sustainability transitions that require support. The fourth and final phase consists of strategising a plan of action to implement the identified lean thinking approach or principle to support the progression of sustainability transitions in healthcare systems. The framework overview is illustrated in Figure 30.

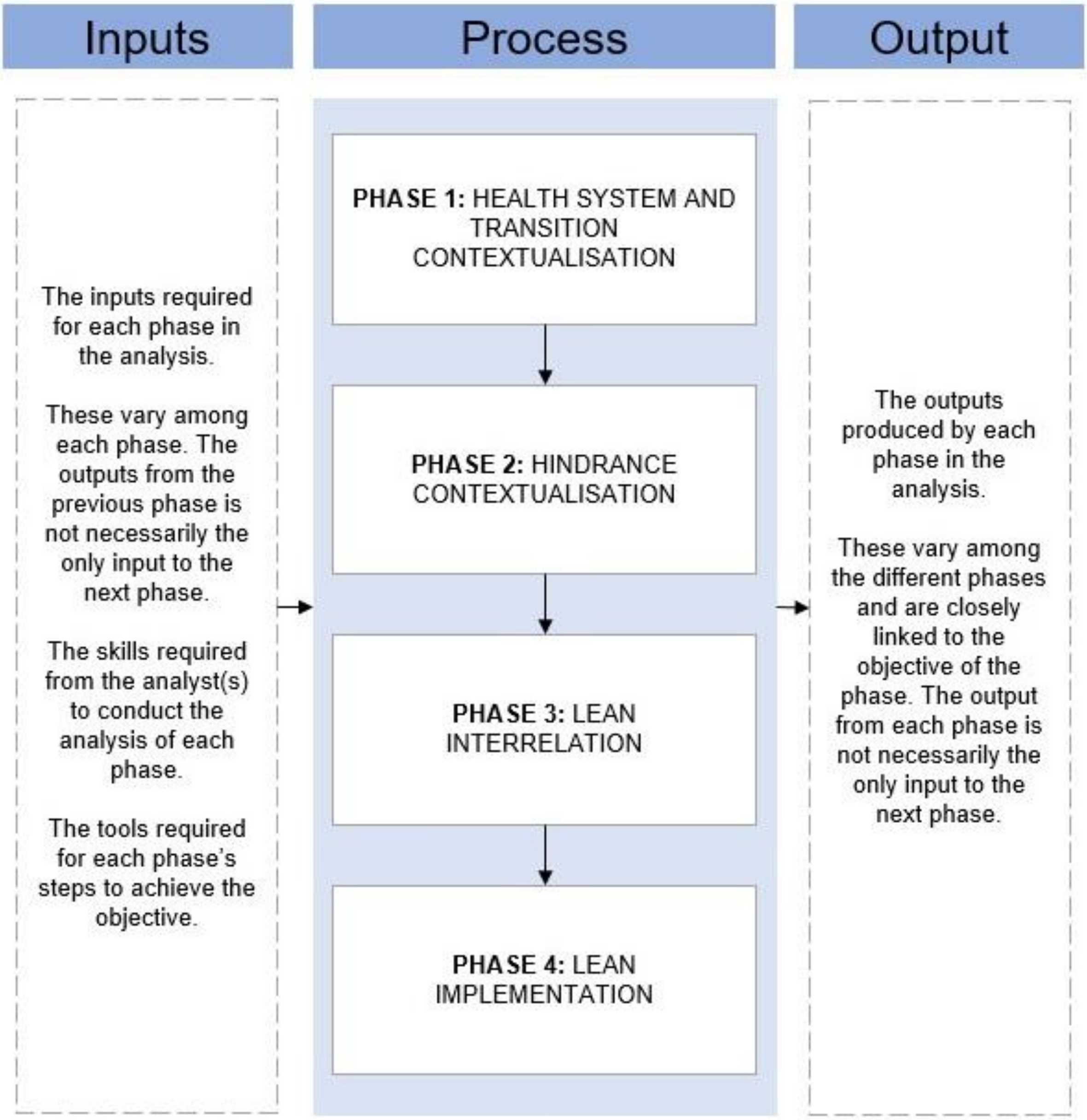


Figure 30: LT4STHC methodology overview

6.6 THE LT4STHC METHODOLOGY

The LT4STHC methodology aims to implement lean thinking approaches and principles to support the progression of sustainability transitions in relation to the healthcare systems. This section elaborates on the four phases of the LT4STHC framework.

PHASE 1: HEALTH SYSTEM AND TRANSITION CONTEXTUALISATION

This phase involves investigating and analysing the healthcare system and the status quo of the sustainability transition of the healthcare system as a socio-technical system.

Phase 1, as illustrated in Figure 31, "health system and transition contextualisation", consists of attempting to understand the healthcare system and the sustainability transition that in relation to the healthcare system. The aim of this phase is to determine the aim and purpose of the sustainability transition relation to the healthcare system. More in-depth applications and requirements are elaborated on in Figure 32.

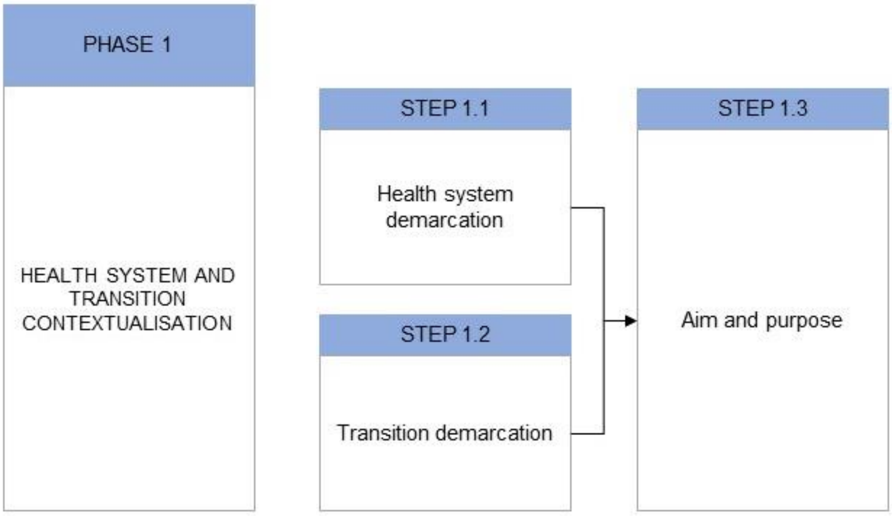


Figure 31: Phase 1 outline

The arrow indicates that the healthcare system and sustainability transition demarcation are two independent processes. However, they are both required to determine the aim and purpose of the sustainability transition in relation to the healthcare system.

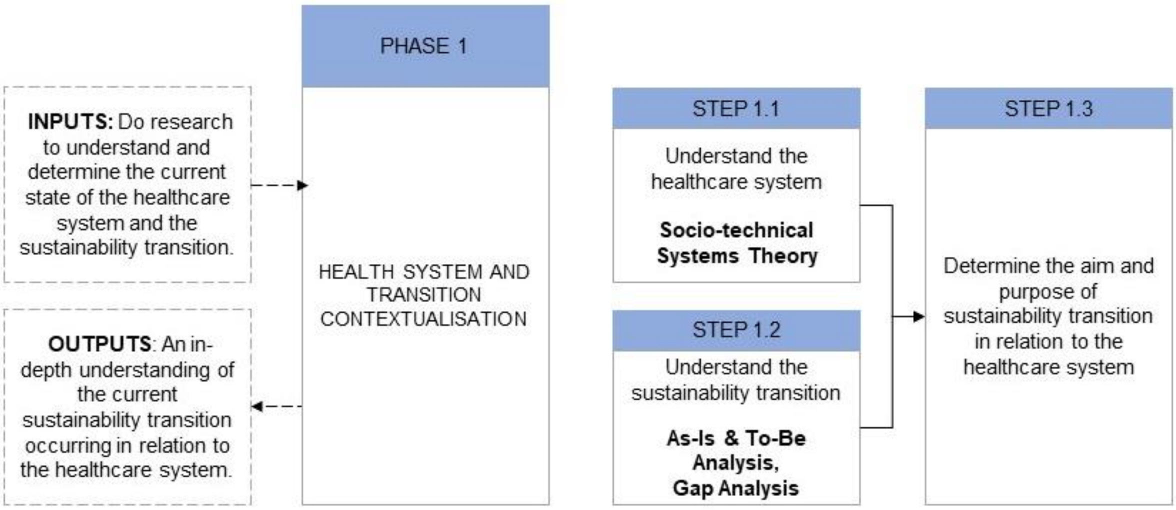


Figure 32: Phase 1 overview

Phase 1 is conducted by following specific steps and methods provided in the overview, as illustrated in Figure 32. The input of phase 1 is conducting research to understand and determine the current state of the healthcare system and the sustainability transition. The output of phase 1 is an in-depth understanding is gained of the current sustainability transition in relation to the healthcare system.

i. Step 1.1 – Healthcare system demarcation: understand the healthcare system

Step 1.1 is conducted to gain the necessary insight into the healthcare system. This step aims to define and identify the healthcare system, enabling the user to demarcate the socio-technical system of interest for the analysis and to define critical information points. As Figure 33 demonstrates, a socio-technical system may be specified in its geographical context within which a sector encompasses the system's activities. Within the sector, multiple industries exist, each with multiple value chains. These value chains can be broken down into specific processes and activities. The framework, methodology, and index's user ought to identify at which level or unit of the analysis they wish to analyse the socio-technical system to apply the LT4STHC framework, methodology, and LT4ST index.

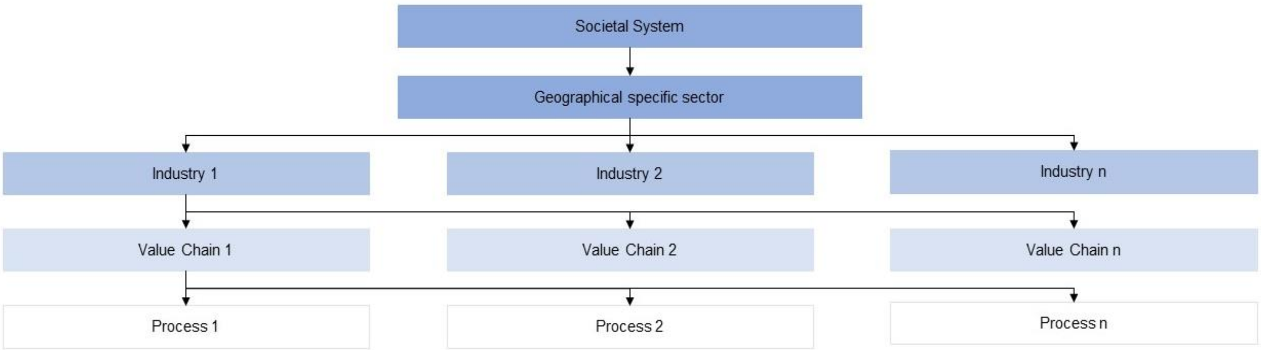


Figure 33: Societal system demarcation differentiation of level of analysis

Once the system has been demarcated into a unit for analysis, the user may proceed with the framework. Du Preez *et al.* (2009) present a "what, why and who" approach, which is adapted as below:

"what": The state of the system with regards to its sustainability and the state of the sustainability transition in relation to the healthcare system;
"why": Factors and drivers for the healthcare system's transition and transformation toward a more sustainable state; and
"who": Various stakeholders in the system, their needs and objectives towards achieving sustainability and sustainable development goals.

The outcome of this step allows the user to understand the healthcare system as a socio-technical system. This step also allows the user to understand in which unit of analysis the framework is being applied.

Example:

The healthcare sector has many industries, which include drugs, medical equipment, managed healthcare, and healthcare facilities. Each of these industries has its own value chains with its respective chain of suppliers, producers, distributors, healthcare providers, and dispensers that provide clinicians with the drugs and supplies they need to take care of patients. Within each of these value chains, there are numerous processes which add value to the value chain.

a. Make use of the "*Socio-technical Systems Theory*" [1] to understand the healthcare system.

[1] Socio-technical Systems Theory - The "*Socio-technical System Theory"* is used to understand and describe the healthcare system. To gain an understanding of the healthcare system, it will be described in terms of the six facets, as illustrated in Figure 34.

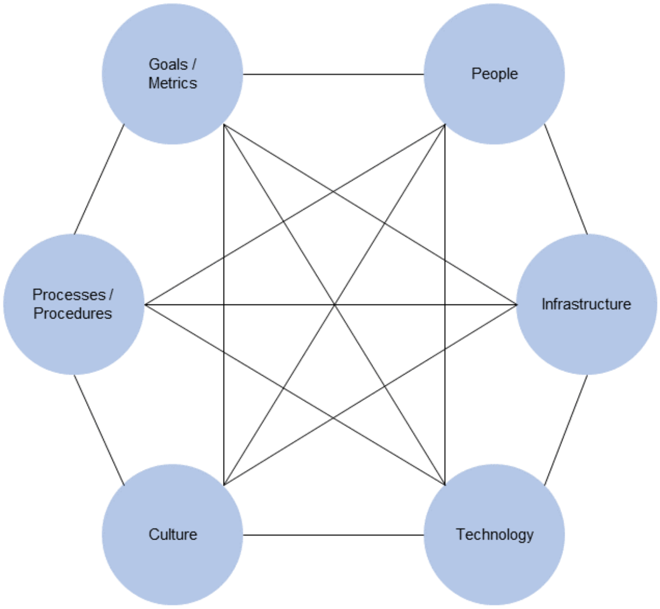


Figure 34: Graphical representation of socio-technical systems theory

Example:

After the healthcare system that will be analysed has been identified, it can be defined in terms of the goals, people, infrastructure, technology, culture, and processes that make up the healthcare system. The goals can include strategic goals or sustainability goals. The people aspect identified key stakeholders of the healthcare system. The infrastructure is the basic physical, organisational structures and facilities of the healthcare system, such as the facilities and their management, and physical infrastructures, such as the hospitals, supply facilities, disposal systems, technical medical equipment, information communication technology (ICT), outreach services, and data.

ii. Step 1.2 – Transition demarcation: understand the sustainability transition

Step 1.2 is conducted to gain the necessary insight into the sustainability transition. This step aims to define and identify the sustainability transition, enabling the user to demarcate the transition of interest for the analysis and to define key informational points for the analysis and the phase of the sustainability transition in which the hindrance is occurring.

The outcome of this step allows the user to understand the sustainability transition that occurs in relation to the healthcare system. This step also allows the user to understand the current state of the sustainability transition, its desired state, and what is required to bridge the gap between the two states.

a. Conduct an "*As-Is Analysis*" [2] to determine the current state of the sustainability transition.

[2] As-Is Analysis - The "*As-Is* Analysis" is employed to assist the user in understanding the current state of the transition under analysis. In the Enterprise Engineering Process, the as-is analysis stage concerns depicting the current system state and doing a critical analysis to determine problem areas (Du Preez *et al*., 2009). The user begins with supporting activity and contextualises the transition

under analysis by identifying and understanding grand-sustainability factors affecting the transition transpiring in the system.

Example:

Identify and understand the problems or issues that occur within the healthcare system and their significance to the value chain of the healthcare system. Problems could include climate change, waste and emissions, water usage etc. Understand other aspects of the healthcare system to understand the current state it is operating in, such as the amount of waste and emissions, water usage, etc. Another factor that could be identified is the current initiatives that are in place to get the healthcare system to its desired state.

b. Conduct a "*To-Be* Analysis" [3] to determine the future state, describing the desired output and goals of the sustainability transition.

[3] To-Be Analysis - The *"To-Be* Analysis" is used to enable the user to understand and determine strategic recommendations for the analysed transition, to address problem and hindrance areas and contribute towards the transition process to a desired "to-be" sustainable state. The user utilises the "to-be" analysis to highlight and identify the objective of the sustainability transition. The LT4STHC framework will then be used (later in this section) to propose possible solutions to the identified hindrance.

Example:

Identify possible strategic or general goals desired in the healthcare system, as the goal describes the desired state to which it aspires.

c. Complete a "*Gap Analysis*" [4] to determine where the system is within the sustainability transition and where it would like to be.

[4] Gap Analysis - The *"Gap* Analysis" is used to enable the user to determine the system requirements or the objective of the sustainability transition and to determine which steps should be taken to meet them. This is illustrated in Figure 35 below.

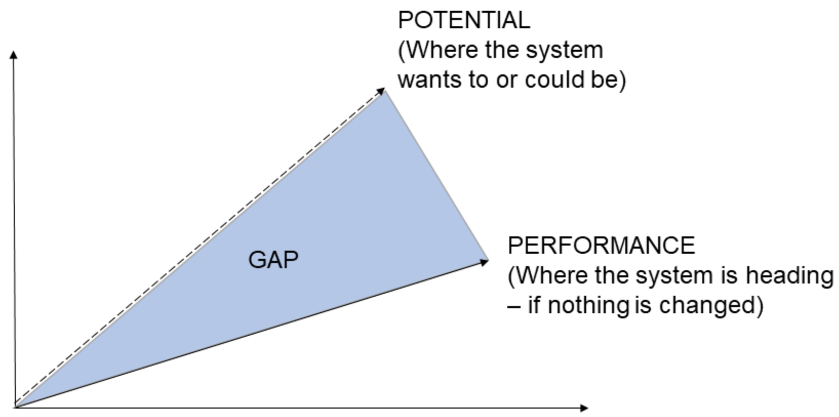


Figure 35: Graphical representation of a gap analysis (author's representation)

Example:

Conduct a type of analysis that indicates the gap between the performance state and the potential state. Examples of gap analysis types include:

I. Fishbone (cause and effect diagram), which helps to identify the root cause of an issue or effect;
II. SWOT analysis, focusing on the strengths and weaknesses of the internal environment and the opportunities and threats in the external environment;
III. McKinsey 7S, which helps to understand gaps that could appear, identify the areas to optimise, align processes, and examine results of future changes;
IV. Nadler-Tushman's Congruence Model, which is used to identify performance gaps; and
V. Burke-Litwin Causal Model can assist in understanding the different components which relate to each other when going through a period of change.

iii. <u>Step 1.3 – Aim and purpose:</u> determine the aim and purpose of the sustainability transition in the healthcare system

Step 1.3 is conducted to understand the aim and purpose of the sustainability transition occurring in the healthcare system. Conclusions will be drawn based on the previous steps in this phase to identify the aim and purpose.

The outcome of this step allows the user to understand the aim and purpose of the sustainability transition in relation to the healthcare system. This step allows the user to understand the reason for implementing the sustainability transition in relation to the healthcare system, which will indicate the greater purpose of the sustainability transition and its desired goal for implementation.

a. Use the results from the previous steps to determine the combined aim and purpose of the sustainability transition within the healthcare system.

Example:

Using the output from the two previous steps, the user will clearly identify the main purpose of the sustainability transition in relation to the healthcare system. By understanding the healthcare system and the sustainability transition in relation to the healthcare system, it will be evident what the intent of the sustainability transition is in relation to the healthcare system. The aim and purpose of sustainability transitions could be to increase the sustainable state of the healthcare system, save costs, decrease resource use, eliminate non-value-adding activities, introduce new technology, etc.

PHASE 2: HINDRANCE CONTEXTUALISATION

This phase consists of identifying the hindrance of the sustainability transition, the cause of the hindrance, and the phase of the sustainability transition the hindrance occurs. Hindrance is defined as something that provides resistance, delay, or obstruction to the progress of the sustainability transition that is occurring in the healthcare system.

Phase 2, as illustrated in Figure 36, "hindrance contextualisation", consists of identifying factors that resist the sustainability transition's progression. More in-depth applications and requirements are elaborated on in Figure 37. The output from phase 1 is an in-depth understanding of the sustainability transition occurring within the healthcare system. The healthcare system is also contextualised to understand the socio-technical system experiencing the sustainability transition.

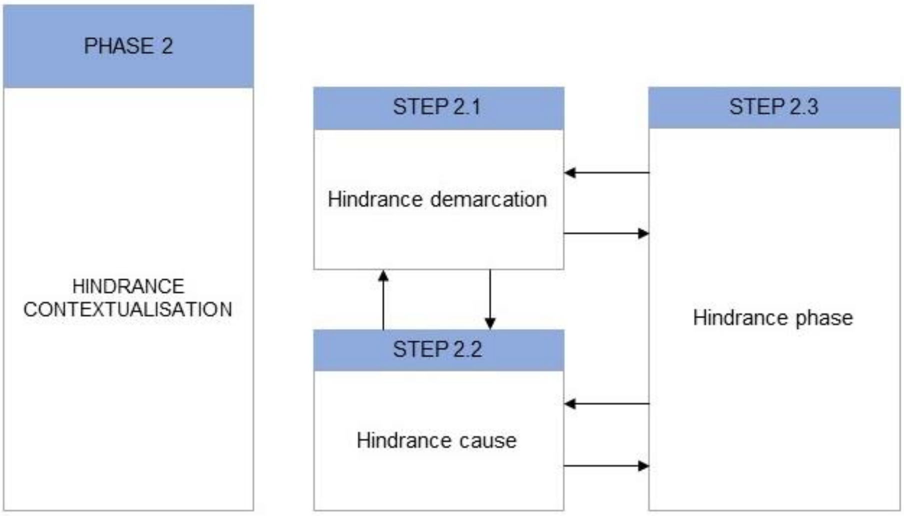


Figure 36: Phase 2 outline

The arrows indicate that all three steps in Phase 2 depend on each other. In order to accurately determine and identify the hindrance, the contextualisation, cause, and the phase where the hindrance to the progress of the sustainability transition in the healthcare system is occurring is required.

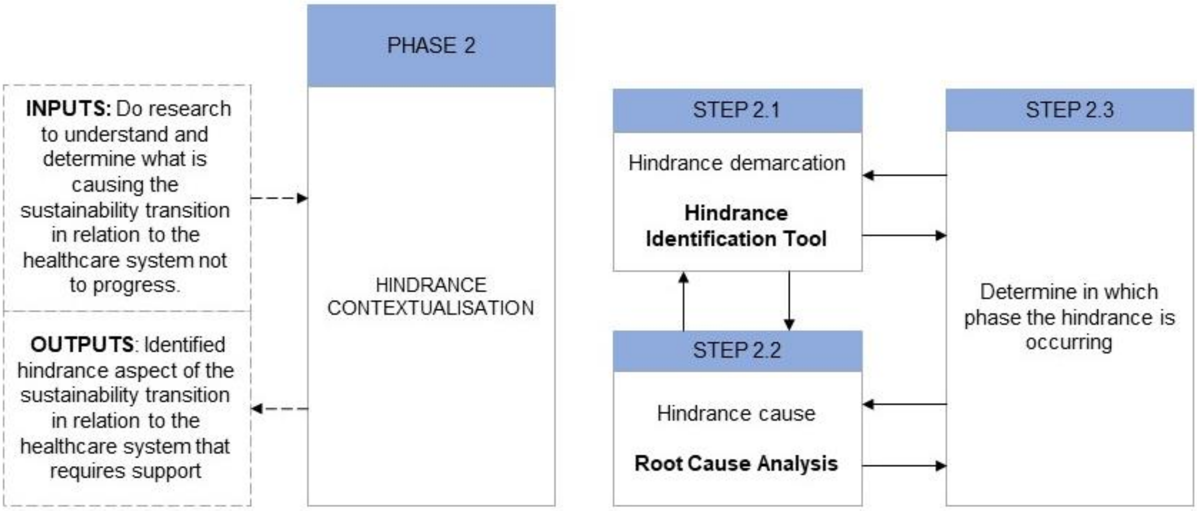


Figure 37: Phase 2 overview

Phase 2 is conducted by following specific steps and methods, which are provided in the overview, as illustrated in Figure 37. The phase 1 output is used to identify possible factors contributing to the lack of progress in the sustainability transition in relation to the healthcare system. The input of phase 2 is conducting research to understand and determine what is causing the sustainability transition not to progress through utilising the author's developed hindrance identification tool. The output of phase 2 is the identification of the hindrance that is contributing to the lack of progress of the sustainability transition in relation to the healthcare system.

iv. Step 2.1 – Hindrance demarcation: identify what contributes to the lack of progress in the sustainability transition.

Step 2.1 is conducted to identify the hindrance occurring in the sustainability transition. The objective is to determine what is causing the sustainability transition not to progress.

The outcome of this step allows the user to identify what is causing the sustainability transition not to progress.

a. Identify the hindrance contributing to the lack of progress in the sustainability transition. The author developed the Hindrance identification tool [5] for this purpose.

[5] Hindrance Identification Tool

The *"Hindrance identification tool"*, as illustrated in Table 31, is proposed to enable the user to identify which aspect lags the sustainability transition progression.

Example:

The hindrance identification tool helps the user to identify possible hindrances that occur within a sustainability transition. The user utilises the hindrance identification tool to identify the type of hindrance they are dealing with. The hindrance identification tool enables the user to identify the hindrance as a landscape tension, regime stress, niche pressure, lack of progress, lack of adaptability, lack of stability, transition and transformational failures, weaknesses, the introduction of new technology, or the occurrence of transition pathways. As an example, if the hindrance is identified as a lack of drivers in the sustainability transition, it means that the hindrance can be identified as a lack of progress.

Table 31: Hindrance identification tool - hindrance type definitions, descriptions, and examples

A hindrance is an occurrence of:	Definition, description, and examples
Forces and Conditions for transitional change	
Landscape tensions	Crisis, exogenous events Standardisation of practices/routines Provision of resources Exercise of power (over the system by external or internal centres of influence) Imposition of a new functioning Undergoing transformation pathways, de-alignment & re-alignment pathways, technology pathways, or reconfiguration pathways. Examples are stated in Table 19 in Section 5.2.1 and can occur in any phase of the sustainability transition.
Regime stresses	Systemic failures Self-regulation of the system Examples are stated in Table 20 in Section 5.2.1 and can occur in any phase of the sustainability transition.
Niche pressures	Presence of a niche Presence of a new demand Presence of a new functioning Examples are stated in Table 21 in Section 5.2.1 and can occur in any phase of the sustainability transition.
Phases of a sustainability transition	
A lack of attention to progress (requires the most) and stability (requires some) in the pre-development phase	**Progress hindrances**: Resistance against those drivers changing the system. It can move the system towards a less sustainable state. Resistance can reduce the impact of transition drivers on transitional progress. System structures are not supporting the establishment of socio-technical niches. A lack of "phasing-out" strategies. **Stability hindrances**: A lack of capacity of the system actors to deal with uncertainty, react to unforeseen events, and recover from shocks. A lack of an envisioned system state with the relevant corresponding sustainability goals and the stability of the transition pathway. No specificity of the goals, the level of clarity, the outreach of communication towards actors, discerned advantages of the envisioned system state in comparison to the current state, and the acceptance.

A hindrance is an occurrence of:	Definition, description, and examples
	Actors do not correspond in terms of what sustainability means in their system. Actors do not develop sustainability goals. Actors do not create an understanding of the problems that need to be addressed. No elaborated vision of the envisioned goal system; a lack of a solid structured and stipulated vision (which can re-focus the system on the original goals). No support for the sustainability transition within the governance system and among the system actors. No awareness of the primary compartments and functions of the system. **Adaptability hindrances**: This could also mean that attention was placed on adaptability, which requires no attention during the pre-development phase. This includes examples such as changing boundary conditions and addressing new situations. They occur in the sustainability transition's pre-development phase (first phase).
A lack of attention to stability (requires the most), progress (requires some), and adaptability (requires the least) in the take-off phase.	**Stability hindrances**: A lack of capacity of the system actors to deal with uncertainty, react to unforeseen events, and recover from shocks. A lack of an envisioned system state with the relevant corresponding sustainability goals and the stability of the transition pathway. No specificity of the goals, the level of clarity, the outreach of communication towards actors, discerned advantages of the envisioned system state in comparison to the current state, and the acceptance. Actors do not correspond in terms of what sustainability means in their system. Actors do not develop sustainability goals. Actors do not create an understanding of the problems that need to be addressed. No elaborated vision of the envisioned goal system; a lack of a solid structured and stipulated vision (which can re-focus the system on the original goals). No support for the sustainability transition within the governance system and among the system actors. No awareness of the primary compartments and functions of the system. **Progress hindrances**: Resistance against those drivers changing the system. It can move the system towards a less sustainable state. Resistance can reduce the impact of transition drivers on transitional progress. System structures are not supporting the establishment of socio-technical niches. A lack of “phasing-out” strategies. **Adaptability hindrances**: No change in boundary conditions. A lack of addressing new situations and responding adequately. Pathway lock-ins. They occur in the take-off phase (second phase) of the sustainability transition.

A hindrance is an occurrence of:	Definition, description, and examples
A lack of attention to adaptability (requires the most), stability (requires some), and progress (requires the least) in the acceleration phase	**Adaptability hindrances**: No change in boundary conditions. A lack of addressing new situations and responding adequately. Pathway lock-ins. **Stability hindrances**: A lack of capacity of the system actors to deal with uncertainty, react to unforeseen events, and recover from shocks. A lack of an envisioned system state with the relevant corresponding sustainability goals and the stability of the transition pathway. No specificity of the goals, the level of clarity, the outreach of communication towards actors, discerned advantages of the envisioned system state in comparison to the current state, and the acceptance. Actors do not correspond in terms of what sustainability means in their system. Actors do not develop sustainability goals. Actors do not create an understanding of the problems that need to be addressed. No elaborated vision of the envisioned goal system; a lack of a solid structured and stipulated vision (which can re-focus the system on the original goals). No support for the sustainability transition within the governance system and among the system actors. No awareness of the primary compartments and functions of the system. **Progress hindrances**: Resistance against those drivers changing the system. It can move the system towards a less sustainable state. Resistance can reduce the impact of transition drivers on transitional progress. System structures are not supporting the establishment of socio-technical niches. A lack of "phasing-out" strategies. They occur in the acceleration phase (third phase) of the sustainability transition.
A lack of attention to stability (require the most) and adaptability (requires some) in the stabilisation phase	**Stability hindrances**: A lack of capacity of the system actors to deal with uncertainty, react to unforeseen events, and recover from shocks. A lack of an envisioned system state with the relevant corresponding sustainability goals and the stability of the transition pathway. No specificity of the goals, the level of clarity, the outreach of communication towards actors, discerned advantages of the envisioned system state in comparison to the current state, and the acceptance. Actors do not correspond in terms of what sustainability means in their system. Actors do not develop sustainability goals. Actors do not create an understanding of the problems that need to be addressed. No elaborated vision of the envisioned goal system; a lack of a solid structured and stipulated vision (which can re-focus the system on the original goals). No support for the sustainability transition within the governance system and among the system actors. No awareness of the primary compartments and functions of the system.

A hindrance is an occurrence of:	Definition, description, and examples
	Adaptability hindrances: No change in boundary conditions; a lack of addressing new situations and responding adequately; and pathway lock-ins **Progress hindrances**: This could also mean that attention was placed on progress, which requires no attention during the stabilisation phase. Active drivers are changing the system. “Phasing-out” strategies are active. They occur in the stabilisation phase (fourth phase) of the sustainability transition.
Transition and Transformational Failures	
Lock-ins	A lock-in occurs in a transition path where innovation does gain influence in the societal system but fails to completely replace the regime co-existing with it in a locked-in state. Lock-ins occur when the unsustainable (incumbent) regime remains to co-exist alongside competing innovations or when competing innovations co-exist. However, these innovation networks need to be more powerful to stabilise the new regime, thus creating a lock-in of innovations. They occur in the acceleration phase (third phase) of the sustainability transition.
System breakdowns	A system breakdown refers to the event where no innovation networks are available that become self-sufficient, and all innovation networks continue to compete for the same resources; this results in no viable alternative being available. Alongside this, a regime destabilises, meaning it can no longer fulfil societal functions. However, because no alternative is available, the system breaks down. They occur in the take-off and acceleration phases (second and third phases) of the sustainability transition.
Backlash	When niches that initially gained power and popularity and thus progressed to the “take-off” phase subsequently fail to become the mainstream practice to meet societal needs, the system experiences backlash. This can happen if, for example, the demand for a certain functioning increase quickly, but the niche cannot cope with changes in demand and thus fails. In another scenario, some novel functioning could be initially adopted by many until unexpected challenges arise, and users no longer adopt the niche as a mainstream practice; in this case, too, backlash can occur. They occur in the take-off and acceleration phases (second and third phases) of the sustainability transition.
Directionality failure	Directionality failure pertains to the observation that a need to consider the direction of innovation in such a way that the innovation contributes towards societal challenges exists. These failures are also associated with one being locked-in in a particular solution that could be more optimal in a long-term perspective. They occur in the take-off and acceleration phases (second and third phases) of the sustainability transition.
Demand articulation failure	Demand articulation failures pertain to the observation that markets for innovations (technologies specifically) may not (yet) exist and could result in a lack of articulation of what these markets require or what user preferences are (results in a lack of being able to anticipate user needs).

A hindrance is an occurrence of:	Definition, description, and examples
	They occur in the take-off and acceleration phases (second and third phases) of the sustainability transition.
Policy coordination failure	Policy coordination failures refer to the observation that policies and institutional standards may need to transform to respond to the challenges and to support the development of innovations to address these challenges adequately. They occur in the take-off and acceleration phases (second and third phases) of the sustainability transition.
Reflexivity failure	Reflexivity failures refer to the observation that there is a need to monitor the development of technology innovations continuously, with regards to such systems contributing to the broader development of adaptation strategies. They occur in the “take-off” and acceleration” phases (second and third phases) of the sustainability transition.
Innovation System Approach	
System weaknesses	No innovating actors, interaction networks, a lack of dependence and interdependence of it on various institutions. A lack of intervention when something goes wrong. A lack of identifying value-adding and non-value-adding activities or system components. No knowledge development and diffusion, no entrepreneurial experimentation, no influence on the direction of search, no resource mobilisation, no market formation, no legitimation, no development of positive externalities. They occur in the take-off phase (second phase) of the sustainability transition.
Strategic Niche Management	
Challenges with introducing and diffusing a new sustainable technology into the societal system	A lack of experimenting. No alignment in technological innovations. No practice of community-building (sharing knowledge, arguments, disagreements, and talks while involving negotiations, games, competitions, etc.). No early participation of all team members; no smooth handover of new technology (could be because of a lack of research and development experiments in the niche market). A lack of continuous learning (could be because of a lack of analysing markets and feedback regularly). Not teaming up with established manufacturers, not offering a variety of products to attract a larger clientele, not offering trial packages, not establishing a hire-purchase for non-visible products or services. A lack of establishing clear targets that become more ambiguous over time, no penalties in the case where these targets are not met, rules are not clearly communicated. They occur in the sustainability transition's pre-development phase (first phase).
Transition Pathways	
Challenges within the transition pathway	Transition pathways are examples of landscape tensions.

A hindrance is an occurrence of:	Definition, description, and examples
	Transformation pathway hindrances: Radical changes without incremental introduction to the new pathways. **De-alignment & re-alignment pathway hindrances**: A lack of multiple niche innovations that co-exists and compete for attention and resources. **Technology pathway hindrances**: No radical innovations. **Reconfiguration pathway hindrances**: No changes in the regime's architecture; the new niche and existing regime do not cooperate. They do not occur in any specific phase of the sustainability transition because these hindrances pertain to the transition pathway that could contain challenges.

v. Step 2.2 – Hindrance cause: identify and determine the contributing factors of the hindrance.

Step 2.2 is conducted to determine the contributing factors to the hindrance.

The outcome of this step allows the user to identify the cause of the hindrance as identified in Step 2.1. Identifying the cause of the hindrance enables the user to determine the activities which led to the occurrence of the hindrance.

a. Conduct a "*Root Cause Analysis"* [6] to discover the cause of why the aspect or phase in the sustainability transition is lacking and thus not allowing the sustainability transition to progress to the next phase.

[6] Root Cause Analysis (RCA)

The *"Root Cause Analysis"* is used to enable the user to identify and document the potential contributing factors of the hindrance of the sustainability transition occurring in the healthcare system. The RCA is utilised because the hindrance that stops the sustainability transition from completing its cycle was identified.

Example:

Categorise the type of problem, whether material, people, or organisational-based problems or hindrances. Ask questions such as how long the problem has existed and the impact of the hindrance. Identify the associated causal factors, such as an increase in ineffective resource use and healthcare waste. Conclude why the hindrance occurred and implement changes to ensure that the hindrance can be overcome, and the sustainability transition can progress.

vi. Step 2.3 – Hindrance phase: identify and determine in which aspect or phase of the sustainability transition the hindrance is occurring.

Step 2.3 is conducted to determine in which phase of the sustainability transition the hindrance occurs.

The outcome of this step will enable the user to identify in which phase of the sustainability transition the hindrance is occurring.

a. Determine the transition phase where the problem occurs, i.e., pre-development, take-off, acceleration, and stabilisation, using the results of the "Transition phase types" as illustrated in Table 32 below. The characteristics and hindrances of each phase are described below.

The table below enables the user to identify and describe the characteristics of the respective transition phases. Using the description of characteristics, the user can determine in which phase of the transition the hindrance is occurring.

Table 32: Transition phase types

Phase type	Characteristics and hindrances
Pre-development phase	i. Dynamic equilibrium and little change are visible within the regime, even though landscape tensions are present. ii. Co-evolutionary regime dynamics increase the interdependencies of the regime, and resultantly the organisation reaches criticality (Van Der Brugge & Rotmans, 2007). iii. The resilience of the system decreases, and it becomes vulnerable.

Phase type	Characteristics and hindrances
	iv. The few changes create stress, thus resulting in actors within the regime putting effort and resources into the improvement efforts to guard against new developments that could threaten the regime (Rotmans *et al*., 2001). v. Challenges are recognised as singular problems, and the provided solutions do not fundamentally solve the challenges, resultantly the fundamental challenges of the system are not addressed (Van Der Brugge & Rotmans, 2007). Recognising challenges as singular problems and thus experiencing path dependency relies on efficiency improvements and incremental changes. vi. The system approaches criticality after time (i.e., system thresholds are being reached) (Van Der Brugge & Rotmans, 2007). vii. Innovations that are isolated, fragmented, improperly embedded, and not sufficiently developed to challenge the existing regime can potentially challenge the incumbent (unsustainable) technologies and are developed to challenge the existing regime (Van Der Brugge & Rotmans, 2007). viii. Innovations emerge in peripheral niches due to experimentation occurring at individual levels (Geels, 2018; Dewulf *et al*., 2009). ix. Not yet a dominant design, and different niches might compete. Actors improvise, experiment with designs, and attempt to align heterogeneous process elements. Niches are supported because actors hope these innovations will eventually replace the current regime (Geels, 2006). The success of the transition in the pre-development phase depends on whether the relation between the transition drivers and resistance against the required changes in the system develops to enable system change (Schilling *et al*., 2018).
Take-off phase	i. The emergence of innovations being developed in niches and the destabilisation of the existing regime occurs (Van Der Brugge & Rotmans, 2007). ii. Regime grows critical, and innovations being developed start to shock the incumbent system causing the triggering of a large-scale change. Change must be triggered; thus, actors must realise the current system's problems. Subsequently, strategies are provided to address the fundamental problems (Van Der Brugge & Rotmans, 2007). iii. Innovations stabilise and enter small market niches (niche regime) (Geels, 2018). iv. New rules are articulated by communities that engage in the market niches, and a new independent path is developed. The users increasingly interact with the alternative. v. Requires resources to develop networks. vi. Competing innovation networks continue to co-exist (lock-ins), or innovation networks are insufficient in becoming self-sustaining, continue to compete for the same resources, and there is no suitable substitute to replace the existing destabilising regime (breakdown). These lag the progression of the transition in this phase. vii. When the strategic intent is not translated into operational objectives, the transition will remain in the take-off phase (Van Der Brugge & Rotmans, 2007). The success of the transition in the take-off phase depends on whether there is an innovation network that can become self-sustaining. Regime structures must open windows of opportunity to allow innovations to enter the system. The transition's ability to progress to the next phase depends on the niche innovations' ability to stabilise and on the co-evolutionary developments in the regime.
Acceleration phase	i. Niches enter the mainstream market and compete with the incumbent regime (Schot *et al*., 2016). ii. Selection rules for policy and implementation change according to the requirements of an emerging alternative regime (indicates that selection power is transferring to an emerging regime). iii. The existing regime undergoes a reconfiguration process that can demand different modes of operation, cooperation, and regulation. Decisions are being made and significantly impact the direction of the transition (Van Der Brugge & Rotmans, 2007).

Phase type	Characteristics and hindrances
	iv. New technology breaks through, widely diffuses, and competes with the existing regime. v. Internal drivers in the niche may relate to price or performance improvements, increasing returns, cycles of processes within the niches, and actors that support the new technologies and drive the diffusion thereof. vi. External drivers are external to the niche (i.e., landscape tensions or regime stress), such as challenges that cannot be met by the existing technologies, weakening the return of existing technologies, etc. (Freeman & Perez, 1988). vii. Changes in policy, regulation, etc., may create favourable environments for alternative technologies (Geels, 2018). These processes create additional windows of opportunity for the emerging regime to grow and increase its power. For the transition to be successful, internal niche processes must align with ongoing processes and tensions in the existing regime and landscape. The existing regime allows for barriers for the emerging niche regime to overcome and may also provide opportunities for such emerging niche regimes to fulfil the requirements and address the tensions and landscape pressures that the existing regime cannot (Geels, 2018). Visible structural changes result from an accumulation of economic, cultural, institutional, and ecological changes (Ehnert *et al*., 2018).
Stabilisation phase	i. The speed of the system change decreases as the new dynamic equilibrium is reached. The new technology replaces the old regime. ii. Changes in the socio-technical regime can still occur, while misalignment could still exist between the new technology and socio-economic dimensions (Geels, 2006). iii. The required technology management activities will vary in each phase. Taking niche development as the start of a transition and demarcated by the notion of transition phases, other transition pathways are considered (Rotmans *et al*., 2001). The destabilisation, decline and phase-out of existing systems and regimes are requirements for successful transitions.

Example:

New policy and regulation changes occur in the socio-technical system, which indicates that the emerging alternative regime gains selection power. By using Table 32 *above, an indication can be obtained whether the sustainability transition is in the acceleration phase of the transition process.*

PHASE 3: LEAN AND HINDRANCE INTERRELATION

This phase determines which lean thinking approach or principle could support the identified hindrance.

Phase 3, as illustrated in Figure 38, "lean and hindrance interrelation", consists of determining which lean thinking approach or principle could assist in supporting the hindrance aspect of the sustainability transition in relation to the healthcare system. More in-depth applications and requirements are elaborated on in Figure 39. The output from phase 2, identified hindrance that causes the sustainability transition not to progress, is used as input for phase 3. The identified hindrance and area of occurrence within the sustainability transition are used to identify which lean thinking approaches and principles could address the hindrance of the sustainability transition in relation to the healthcare system.

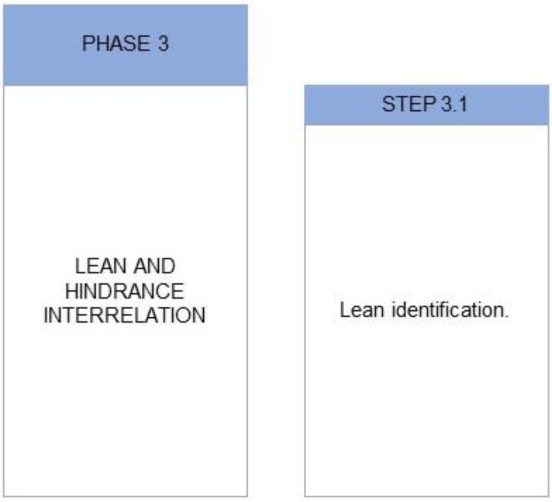


Figure 38: Phase 3 outline

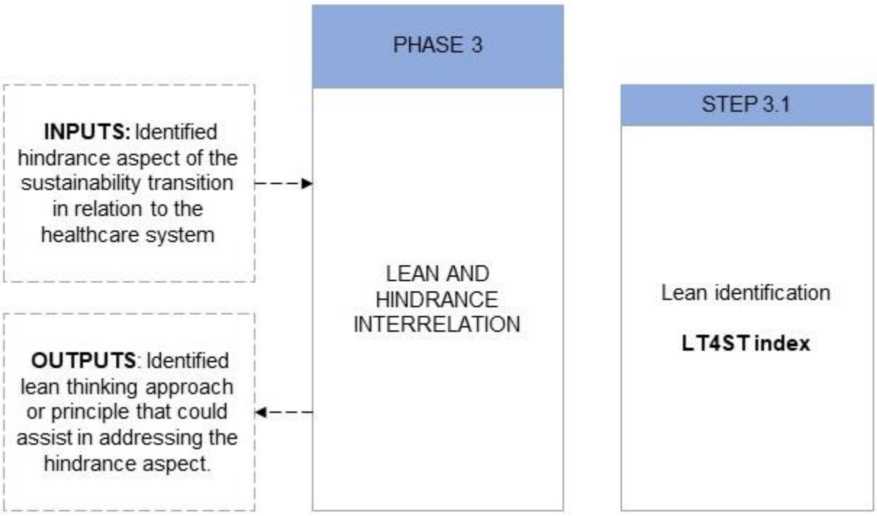


Figure 39: Phase 3 overview

Phase 3 is conducted by following specific steps and methods provided in the overview, as illustrated in Figure 39. The phase 2 output is used in conjunction with the author's developed hindrance identification tool as input for this phase. The input of phase 3 is the identified hindrance aspects of the sustainability transition in relation to the healthcare system. This hindrance is contributing to the lack of progress in the transition process of the sustainability transition in relation to the healthcare system. The output of phase 3 is the identification of lean thinking approaches and principles that could be implemented to address the hindrance aspect of the sustainability transition in relation to the healthcare system. Addressing the hindrance aspect through lean thinking implementation supports the progression of the sustainability transition in relation to the healthcare system.

vii. <u>Step 3.1 – Lean identification:</u> identify lean approaches or principles that could address the hindrance that is causing the sustainability transition in healthcare not to progress.

Step 3.1 is conducted to determine which lean thinking approach or principle could contribute to addressing the factors, elements, and actions hindering the sustainability transition in the healthcare system. The objective of this step is to use the LT4STHC framework and LT4ST index to allocate lean thinking to the identified hindrance to the progression of the sustainability transition. The allocated lean thinking will depend on the phase of the sustainability transition and the contributing factors of the hindrance.

The outcome of this step enables the user to identify the appropriate lean thinking approach or principle to implement to address the identified hindrance of the sustainability transition in healthcare.

a. Utilise the "*LT4STHC framework*" [7] to identify which lean thinking approach or principle could be used to support the identified hindrance aspect. The LT4STHC framework methodology will be the approach to assist in determining the required lean thinking approaches and principles that can be implemented to ensure that the sustainability transition has no hindrance and progresses without any disruptions.

[7] LT4STHC Framework

The objective is to enable the user to identify applicable and appropriate lean thinking approaches and principles that could assist the identified hindrance of the sustainability transition in relation to the healthcare system. This process is conducted using the developed LT4STHC framework and index. Lean thinking approaches and principles were analysed to determine how and where they could be applied during a sustainability transition to ensure that the sustainability transition completes its cycle.

Example:

As illustrated in Table 31, the hindrance identification tool is used to identify that the hindrance is a pathway lock-in. The lock-in's cause is identified as a new emerging innovation that gains influence in the socio-technical system but fails to replace the regime and thus co-exist in a locked-in state.

This example could include the newly developed "David Abney: Drone-delivered medical supplies", which gains influence in the healthcare system. However, it fails to replace the regime of the current methods of delivering medical supplies.

Using Tables 31 and 32, it is identified that the pathway lock-in occurs in the acceleration phase of the sustainability transition.

According to the LT4STHC framework, as illustrated by Figure 29 in Section 6.4, close attention needs to be paid to the adaptability in that phase of the sustainability transition (refer to Table 54*, Lean4Adaptability in Appendix B). Attention needs to be paid to stability (refer to Table* 53*, Lean4Stability in Appendix B), and only some attention needs to be paid to progress (refer to Table* 52*, Lean4Progress in Appendix B). It is also essential to keep the transition flexible as more system structures gain the opportunity to change along the transition pathway, causing the lock-in due to a lack of adaptability.*

Using the tables as mentioned above, paying close attention to adaptability (as the cause of the hindrance was a pathway lock-in (also a failure, as illustrated by Table 55*, in Appendix B). It is identified that adaptability still requires much attention when dealing with a pathway lock-in. An APPS can be utilised to determine the "what should happen?". An APPS identifies which lean thinking approaches or principles assist in answering that question.*

The corresponding lean thinking approaches and principles in Lean4Adaptability and Lean4Failures will be considered.

<u>4P MODEL OF THE TOYOTA WAY & LIKER'S LEAN:</u>

I. Kaizen
II. Genchi Genbutsu
III. Slow decision-making
IV. Create process flow
V. Pull system

VI. Jidoka

<u>LEAN PRACTICES & APPROACHES:</u>

I. Leadership & Management
II. Employee Involvement
III. Tools & Techniques
IV. Six Sigma

<u>LEAN PRINCIPLES:</u>

I. Reducing uncertainty
II. Focus on customer requirements
III. Increase production flexibility
IV. Increase process transparency
V. Controlling the entire process
VI. Improving the process continuously

Only considering the lean thinking approaches and principles that correspond in Lean4Adaptability and Lean4Failures, ensures that both the lock-in being a failure and the lack of adaptability in the transition are addressed.

PHASE 4: LEAN IMPLEMENTATION

This phase consists of determining a plan of action for implementing the identified lean thinking approach or principle that could support the aspect or phase in the sustainability transition in relation to the healthcare system that requires attention for the sustainability transition to progress.

Phase 4, as illustrated in Figure 40, "lean implementation", consists of determining a plan of action for implementing the identified lean thinking approach or principle that could ensure sustainability transitions in healthcare are supported. More in-depth applications and requirements are elaborated on in Figure 41.

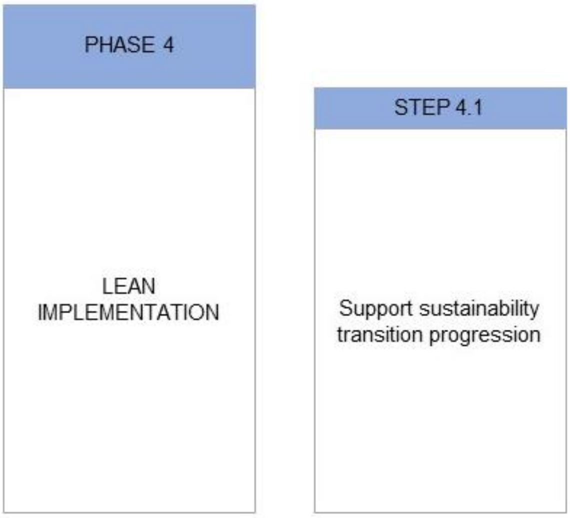


Figure 40: Phase 4 outline

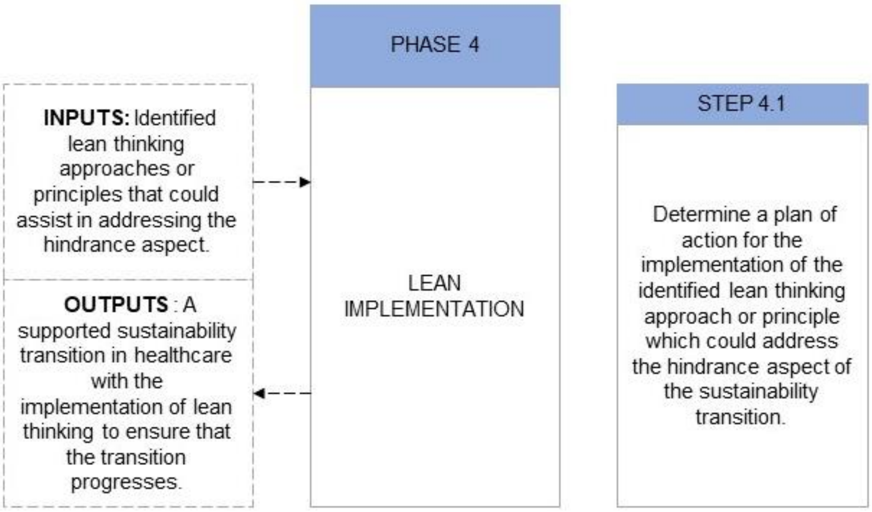


Figure 41: Phase 4 overview

Phase 4 is conducted by following specific steps and methods provided in the overview, as illustrated in Figure 41. Phase 3 output is used as input for this phase. The input of phase 4 is the identified lean thinking approaches and principles that could assist in addressing the hindrance aspect of the sustainability transition in relation to the healthcare system. The output of phase 4 is a sustainability transition in relation to the healthcare system that is supported to progress with implementing lean thinking approaches and principles.

viii. <u>Step 4.1 – Support sustainability transition progression:</u> determine a plan of action

Step 4.1 is conducted to determine a plan of action for the identified lean thinking approaches or principles, as done with the assistance of the LT4STHC framework, that could contribute to supporting the sustainability transition in relation to the healthcare system. The objective is to enable the user to determine a plan of action to implement the identified lean thinking approach or principle into the sustainability transition in relation to the healthcare system.

The outcome of this step enables the user to develop a plan of action to implement the identified lean thinking approaches or principles that could assist in addressing the lock-in caused by a lack of adaptability in the sustainability transition in healthcare.

a. Discuss and determine why and how the identified lean thinking approach or principle (as determined by using the "*LT4STHC framework*") can support the identified hindrance, which will assist in ensuring the successful progress of a sustainability transition in the healthcare system.

Example:

The newly developed "David Abney: Drone-delivered medical supplies" is gaining influence in the healthcare system. However, it fails to replace the regime of the current methods of delivering medical supplies.

The identified lean thinking approaches and principles that could be implemented to address this pathway lock-in are:

<u>4P MODEL OF THE TOYOTA WAY & LIKER'S LEAN:</u>

I. Through Kaizen, continuous organisational learning can be implemented (continuous improvement, prompting employees to come up with solutions).

II. Genchi Genbutsu: physically going to and observing a location (and its conditions) to understand and solve problems faster and more effectively
III. Slow decision-making by consensus, considering all options (rapid implementation)
IV. Create process flow
V. Use a pull system to avoid overproduction.
VI. Jidoka: stop a process when there is a quality problem; automation with a human touch to help workers daily

<u>LEAN PRACTICES & APPROACHES:</u>

I. Leadership and management: an in-depth understanding of the lean journey to manifest a lean culture; skilled people are used in the right place
II. Employee involvement: ensure willingness to change; employee development (human capital)
III. Tools & Techniques
IV. Six Sigma: reduce the occurrence of defects in products/services; speeds up deliveries, reduces costs, increases the quality

<u>LEAN PRINCIPLES:</u>

I. Reducing uncertainty
II. Focus on customer requirements
III. Increase production flexibility
IV. Increase process transparency
V. Improving the process continuously

The identified lean thinking approaches or principles could address the pathway lock-in and the lack of adaptability in the sustainability transition in healthcare. The example of the “David Abney: Drone-delivered medical supplies” these principles could assist in the following manners:

I. Continuously learning through continuous improvement and letting workers think of solutions could assist in coming up with solutions quickly and adequately to solve the lock-in.
II. Physically observing the existing method of medical supply delivery systems. For example, the distribution centres where the trucks load their medical supplies could assist in identifying why the new emerging innovation is not breaking through to the market over the current method of medical supply delivery.
III. Slow decision-making and considering all options could ensure that all possible solutions are considered before the new emerging innovation is introduced.
IV. Creating process flow is an obvious solution to increasing the adaptability of a transition.
V. Using the pull system could assist in addressing the lock-in because the innovation will only be produced or introduced as the demand for it increases.
VI. Stopping when there is a quality problem could also assist the pathway lock-in as it could be why the new emerging innovation does not gain the required “popularity”.
VII. A lean culture is ensured, and adequately skilled people in the right place could assist in addressing the lack of adaptability as the lean culture concerns value creation and waste elimination. Having people in the right places in the system with the required skills could assist in addressing the pathway lock-in because their experience will allow them to make informed decisions and find adequate solutions.
VIII. Employee involvement can support adaptability by considering all options and being flexible during the sustainability transition process.

IX. *Tools and techniques, such as Error Proofing, Root Cause Analysis, Process Flow Map, Change management plan, Poka Yoke (mistake proofing), and Kanban (a mechanism to flow control and production control allowing the production of only what is needed at the moment when it is needed in quantity needed), can be used to address the pathway lock-in or increase the adaptability of the sustainability transition concerning the healthcare system.*

X. *Implementing Six Sigma can assist in addressing the pathway lock-in by reducing the occurrence of defects, speeding up the delivery time, reducing costs and increasing the quality of the new emerging innovation.*

XI. *Reducing uncertainty and increasing process transparency could assist in addressing the pathway lock-in by allowing a broader and more accurate scope of the entire pathway to be investigated and considered when making decisions.*

XII. *Focusing on customer requirements could assist in addressing the pathway lock-in by listening to what the customer wants and only supplying what they require.*

XIII. *The increase in production flexibility could assist in addressing the adaptability of the sustainability transition concerning the healthcare system.*

XIV. *The continuous improvement of the process can assist in addressing the pathway lock-in by coming up with solutions quickly and adequately to solve the lock-in.*

6.7 CHAPTER 6: CONCLUSION

In this chapter, the developed LT4STHC framework and methodology have been presented. The methodology utilises different Industrial Engineering approaches and the developed LT4STHC framework to achieve the aim of this research, which is to support sustainability transitions in healthcare. The developed framework used the requirement specifications to ensure that the framework is developed correctly and achieves its intended purpose. This was also supported by using Van Aken *et al.* (2007)'s process management. The finalised design is presented in this chapter. Developing the framework was initiated with an informal sketching process, formally presented through an outline design in Figure 30 in Section 6.4. A detailed design was elaborated in Section 6.5 and graphically presented. The framework and operationalisation strategy development made use of an applied systems thinking approach as construct guidance. Table 33 below summarises the applied systems thinking principles and where they are utilised in developing the LT4STHC framework and operationalisation strategy.

Table 33: Systems thinking principles application

	Systems Thinking Principle	Parts applied to the LT4STHC framework or operationalisation strategy
1.	Understand the system structure	Perspectives and aspects of the framework (Sections 6.2 and 6.3)
2.	Understand the dynamic behaviour of the system	LT4STHC framework components (Section 6.3)
3.	Reduce complexity through conceptual modelling	LT4STHC framework representation (Sections 6.3 and 6.4) Operationalisation strategy conceptual representation (Section 6.5)
4.	Understand the system at different scales	Operationalisation strategy (Section 6.5)

CHAPTER 7: EVALUATION PROCESS

In this chapter, as illustrated in Figure 42, an evaluation of the research and its products is presented. The framework verification is based on the set of requirement specifications developed in Chapter 4 and the theoretical verification of the framework through consulting subject matter experts (SMEs). For validation purposes, SMEs are interviewed and are requested to complete a questionnaire to provide confidence in the applicability, practicability, and usability of the developed framework. A case study application is also presented as part of the validation process.

This chapter commences with an introduction to the evaluation process in Section 7.1, which details the methodologies used to verify and validate the LT4STHC framework and methodology. Thereafter, Sections 7.2 and 7.3 elaborate on the verification of the research conducted through the author's self-evaluation of the LT4STHC framework, methodology and LT4ST index against the requirement specifications. The second verification process was to gather feedback from SMEs and have them complete a verification questionnaire. Sections 7.4 to 7.6 about the research validation is conducted through engagement with SMEs and having them complete a validation questionnaire. The validation process is concluded with a case study application of the LT4STHC framework and methodology. The evaluation process is presented to fulfil the RO5 (refer to Section 1.3).

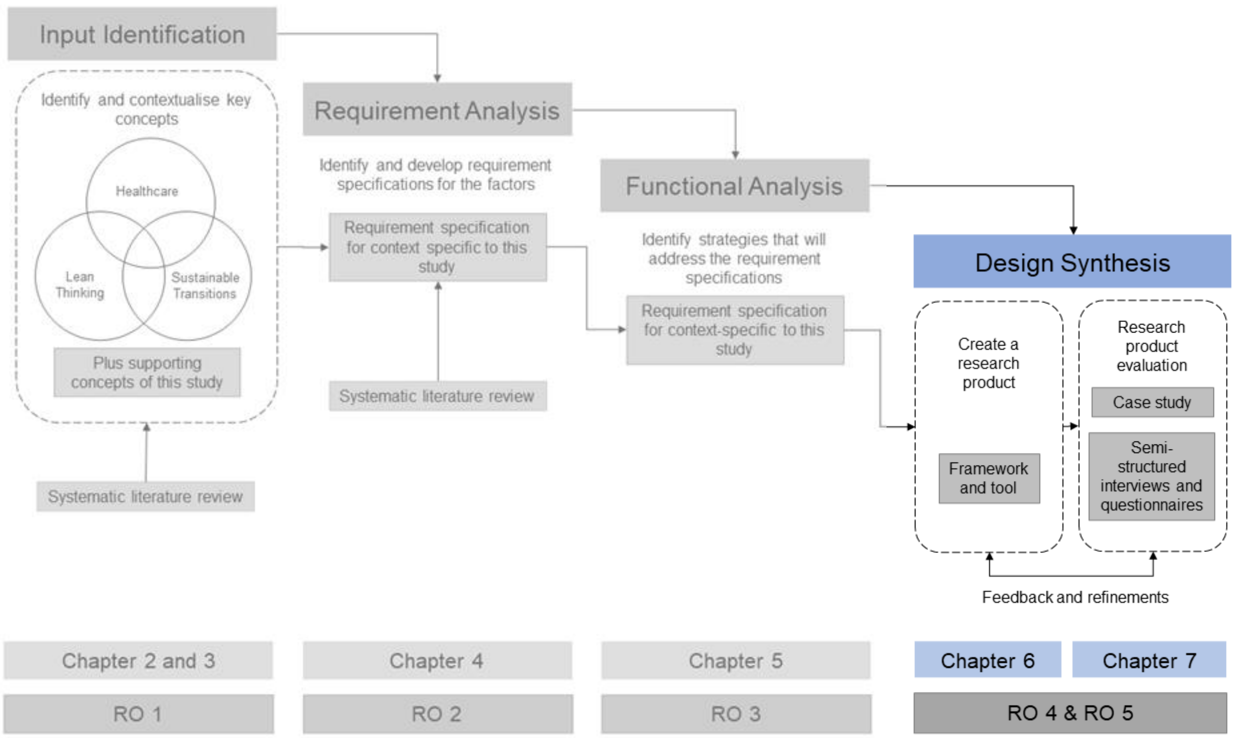


Figure 42: Design synthesis, research products' evaluation of an adapted systems engineering approach

7.1 EVALUATION PROCESS: INTRODUCTION

The evaluation is required to evaluate the research findings and proposed framework. According to Brade *et al.* (2003), evaluation is categorised into two dimensions: verification and validation. These dimensions aim to increase the credibility of models and the research findings by furnishing evidence of correctness and indicating suitability. The key differences between verification and validation in terms of the various dimensions they evaluate are illustrated in Figure 43.

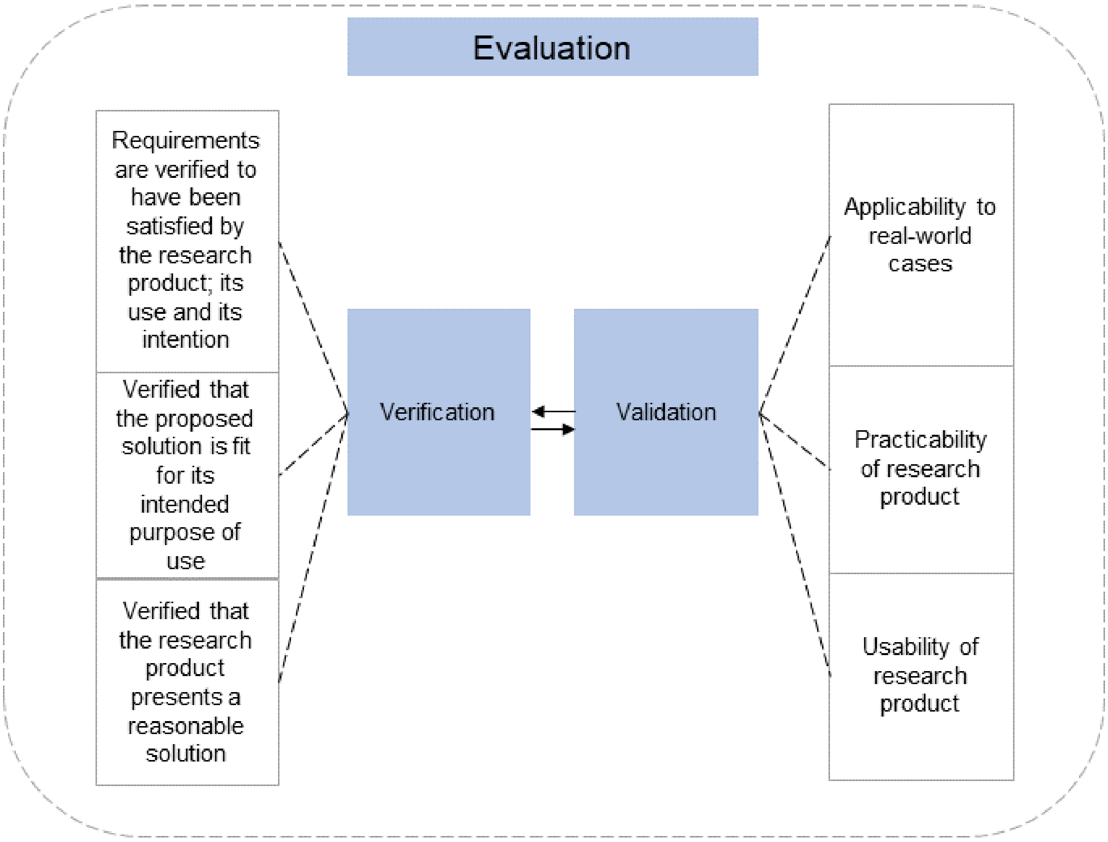


Figure 43: Verification and validation outcomes (adapted from (De Kock, 2020))

Verification is typically concerned with the design and methods employed in research, whereas validation is aimed at measuring the research outcome. Conwell *et al.* (2000) provide distinct definitions of the verification and validation process:

Verification is defined as:

"*The process of determining that a model or simulation implementation presents the developer's conceptual description and specifications with sufficient accuracy"* (Conwell *et al*., 2000).

Whereas validation is defined as:

"The process of determining the degree to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model" (Conwell *et al*., 2000).

The verification process evaluates to what extent the LT4STHC framework and LT4ST index satisfy the requirement specifications provided for its development, as well as an evaluation of the theoretical consistency of the developed framework, methodology, and index. The verification process is conducted to confirm that the research products are built correctly (Bekker, 2018), and thus ensures the theoretical correctness of the research products' content and affirm that the research products present a reasonable theory. Theoretical verification was conducted in two ways:

i. By means of an evaluation of the LT4STHC framework, methodology, and LT4ST index, against the requirement specifications for its development; and
ii. By means of the verification of parts of the LT4STHC framework and methodology.

The LT4STHC framework and methodology are validated to confirm whether the correct framework, methodology and LT4ST index have been developed for their intended purposes. Validation, therefore, tests how well the research products jointly address the implementation of lean thinking to support sustainability transitions in healthcare (Bekker, 2018). Validation also identifies the research products' applicability, usability, and practicability. Validation is thus done to achieve the following:

i. Operational validation to ascertain whether the framework, methodology and index conceptualisation of the use of lean thinking to support sustainability transitions in healthcare applies to the real world through a case study application; and
ii. Credibility ensures that the end users have confidence in utilising the research products to understand the use of lean thinking to support sustainability transitions and apply this understanding to relevant real-world scenarios.

The evaluation strategy used to verify and validate the LT4STHC framework and methodology is illustrated in Figure 44.

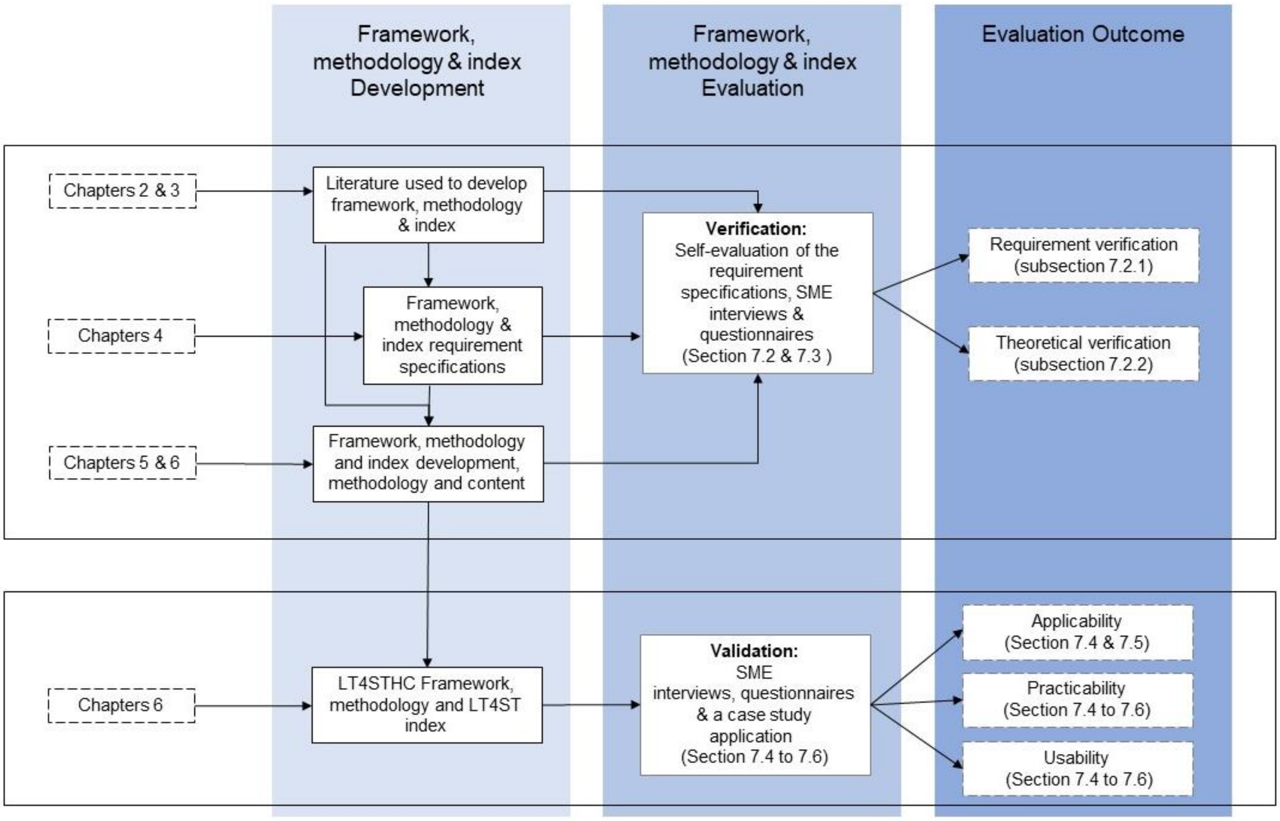


Figure 44: LT4STHC framework, methodology, and LT4ST index evaluation process

Based on their experience and expertise in sustainability and sustainability transitions, healthcare, and lean, SMEs were approached to participate in the evaluation process. These participants are listed in Table 34 below.

Table 34: SME profiles

SME ID	Position and relevant experience	Relevant knowledge area
SME 1	Post doctorate research fellow. BPhysT; BEng (Industrial); MEng (Industrial); PhD (Industrial)	Health systems, Industrial Engineering
SME 2	Lecturer at University. MScEng (Mechanical); Postgrad Dip in HE; PhD HE	Industrial Engineering, Lean implementation

SME ID	Position and relevant experience	Relevant knowledge area
SME 3	Process Improvement Engineer. BEng (Industrial)	Health systems, Industrial Engineering, Lean implementation, Sustainability.
SME 4	General Manager of a hospital. BEng (Industrial); MSc (Industrial Engineering)	Health systems, Industrial Engineering, Lean implementation.
SME 5	General Manager of a hospital group. BSc (Physiotherapy); MBA	Health systems.
SME 6	Continuous Improvement Engineer. MSc (Logistics); MBA	Health systems, Lean implementation, Sustainability.

7.2 VERIFICATION

This section deals with the first stage, verification, of the evaluation strategy for this research study. The verification of the LT4STHC framework, methodology, and LT4ST index is based on a set of requirement specifications developed in Chapter 4 and the theoretical verification of the framework, methodology, and index. Thus, a two-part verification is conducted. Firstly, the verification of the requirement specifications set for the LT4STHC framework and methodology is conducted to assess how the requirement specifications are addressed in the proposed framework, methodology, and index. This step indicates how the framework, methodology, and index adhere to the guidelines provided throughout the literature study. The second part of the verification concerns performing semi-structured interviews and SMEs completing questionnaires to verify the theoretical integrity of the developed LT4STHC framework and methodology. The goal of the verification process was to enable the emergence of possible refinements to the research products. Information that led to corrections and refinements for the LT4STHC framework was obtained through input provided and insights gained from comments and feedback provided by the SMEs during the interviews and questionnaires. The suggested refinements are included in the final presentation of the LT4STHC framework.

7.2.1 EVALUATION OF REQUIREMENT SPECIFICATIONS

The verification process also entailed evaluating that the final LT4STHC framework, methodology, and LT4ST index meet the required specifications for its development, as presented in Section 4.2. The approach that was followed is based on the approaches taken by Kennon (2017) and De Kock (2020).

The requirement specifications in each category have been allocated to components of the framework, methodology, and index (refer to Table 29 in Section 6.2) and are therefore self-evaluated against those individual components. Table 35 below illustrates the self-evaluation of the requirement specifications and shows each requirement specification where the fulfilment is regarded as evident. A total of nineteen requirement specifications are provided in Table 35 for the framework, methodology, and index's development within the four categories, i.e., functional requirements (FR), user requirements (UR), design restrictions (DR), attention points (AP), and boundary conditions (BC) as specified by Van Aken *et al.* (2007). The self-evaluation is conducted through a descriptive address or tick mark as applicable.

Table 35: Verification of requirement specifications

Requirement Specification ID	Requirement Specification Description	LT4STHC framework features			LT4STHC framework methodology feature						LT4STHC framework & methodology elements	
		Lean thinking allocation to various aspects of sustainability transition in relation to healthcare systems	The use of transition management to establish socio-technical system shifts	Use of MLP, ISA, SNM which facilitates that a socio-technical perspective is utilised	Using " Socio-technical System's Theory" to understand the healthcare system	As-Is & To-Be Analysis	Gap Analysis	Root Cause Analysis	Plan of action for lean implementation in sustainability transition in relation to healthcare	Case study application	LT4STHC framework & methodology evaluation	LT4STHC framework & methodology reporting template
Functional Requirements												
FR1	The research products should sufficiently integrate lean thinking into sustainability transitions in healthcare.	✓	-	-	-	-	-	-	✓	-	-	-
FR2	The research products should approach sustainability transitions from a socio-technical transition perspective.	-	✓	✓	✓	-	-	-	-	-	-	-
FR3	The research products should incorporate an understanding of lean thinking in healthcare within a holistic context**.**	✓	-	-	-	-	-	-	-	-	-	-
FR4	The research products should apply to socio-technical systems.	-	✓	✓	✓	-	-	-	-	-	-	-

		LT4STHC framework features			LT4STHC framework methodology feature						LT4STHC framework & methodology elements	
Requirement Specification ID	**Requirement Specification Description**	**Lean thinking allocation to various aspects of sustainability transition in relation to healthcare systems**	**The use of transition management to establish socio-technical system shifts**	**Use of MLP, ISA, SNM which facilitates that a socio-technical perspective is utilised**	**Using " Socio-technical System's Theory" to understand the healthcare system**	**As-Is & To-Be Analysis**	**Gap Analysis**	**Root Cause Analysis**	**Plan of action for lean implementation in sustainability transition in relation to healthcare**	**Case study application**	**LT4STHC framework & methodology evaluation**	**LT4STHC framework & methodology reporting template**
User Requirements												
UR1	The research products should be understandable and unambiguous.	-	-	-	-	-	-	-	-	✓	✓	✓
UR2	The research products should be clear and concise.	-	-	-	-	-	-	-	-	✓	✓	✓
UR3	The research products should provide clear definitions and explanations to cater to a broad range of experience levels in lean, sustainability transitions, and healthcare.	-	-	-	-	-	-	-	-	✓	✓	-
UR4	Practical implementation strategies and utility should accompany the research products because it is developed from an engineering perspective.	-	-	-	-	-	-	-	-	✓	✓	✓

		LT4STHC framework features			LT4STHC framework methodology feature						LT4STHC framework & methodology elements	
Requirement Specification ID	**Requirement Specification Description**	**Lean thinking allocation to various aspects of sustainability transition in relation to healthcare systems**	**The use of transition management to establish socio-technical system shifts**	**Use of MLP, ISA, SNM which facilitates that a socio-technical perspective is utilised**	**Using " Socio-technical System's Theory" to understand the healthcare system**	**As-Is & To-Be Analysis**	**Gap Analysis**	**Root Cause Analysis**	**Plan of action for lean implementation in sustainability transition in relation to healthcare**	**Case study application**	**LT4STHC framework & methodology evaluation**	**LT4STHC framework & methodology reporting template**
Design Restrictions												
DR1	The research products are developed from an Industrial Engineering perspective, as it is the discipline of this research. SMEs could add other inputs from other disciplines in specific fields of research.	✓	✓	-	✓	✓	✓	✓	-	✓	-	-
DR2	The research products do not provide new meaning or theory around lean thinking and sustainability transitions. However, it integrates lean thinking into sustainability transitions in healthcare using theory and examples from literature resources.	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓
DR3	The research products exclusively take a socio-technical transition perspective towards sustainability transitions.	-	✓	✓	✓	-	-	-	-	-	-	-

		LT4STHC framework features			**LT4STHC framework methodology feature**						**LT4STHC framework & methodology elements**	
Requirement Specification ID	**Requirement Specification Description**	**Lean thinking allocation to various aspects of sustainability transition in relation to healthcare systems**	**The use of transition management to establish socio-technical system shifts**	**Use of MLP, ISA, SNM which facilitates that a socio-technical perspective is utilised**	**Using " Socio-technical System's Theory" to understand the healthcare system**	**As-Is & To-Be Analysis**	**Gap Analysis**	**Root Cause Analysis**	**Plan of action for lean implementation in sustainability transition in relation to healthcare**	**Case study application**	**LT4STHC framework & methodology evaluation**	**LT4STHC framework & methodology reporting template**
Attention Points												
AP1	The research products should aid as a guide in academic research about the key topics of this research, being lean thinking implementation to facilitate and support sustainability transitions in healthcare.	✓	✓	✓	✓	-	-	-	✓	-	-	✓
AP2	The research products' guidelines and solutions should not exceed the required limit of expectations.	-	-	-	-	-	-	-	-	-	-	✓
AP3	The research products should be used when particular sustainability needs are identified and highlighted.	✓	-	-	-	-	-	-	-	-	-	-
AP4	The research products may be the approach to developing a deeper understanding of novel sustainability transitions that include lean thinking.	✓	-	-	-	-	-	-	✓	-	-	-

Requirement Specification ID	Requirement Specification Description	LT4STHC framework features			LT4STHC framework methodology feature						LT4STHC framework & methodology elements	
		Lean thinking allocation to various aspects of sustainability transition in relation to healthcare systems	The use of transition management to establish socio-technical system shifts	Use of MLP, ISA, SNM which facilitates that a socio-technical perspective is utilised	Using " Socio-technical System's Theory" to understand the healthcare system	As-Is & To-Be Analysis	Gap Analysis	Root Cause Analysis	Plan of action for lean implementation in sustainability transition in relation to healthcare	Case study application	LT4STHC framework & methodology evaluation	LT4STHC framework & methodology reporting template
Boundary Conditions												
BC1	The research products are most appropriate for the application to healthcare systems in the quest to fulfil sustainability targets and overcome challenges experienced in healthcare.	✓	-	-	✓	-	-	-	✓	-	-	-
BC2	The research products must be utilised by users with prior knowledge of the concepts.	-	-	-	-	-	-	-	-	✓	✓	✓
BC3	The research products can only be applied with contextual contributions from the users.	-	-	-	-	-	-	-	-	-	✓	-
BC4	The research products are exploratory in the application and are not to be used as a prescribed method to integrate lean thinking in sustainability transitions in healthcare.	-	-	-	-	-	-	-	-	✓	✓	✓

In Table 35 each requirement specification is considered and compared to different aspects of the framework, methodology, and index conceptually. The requirement specifications have been confirmed to have been satisfied by the use and intention of the framework, methodology, and index.

7.2.2 THEORETICAL VERIFICATION AND REFINEMENT

The theoretical verification and refinement were done through semi-structured interviews and SMEs' completion of questionnaires (refer to Figure 49 in Appendix C). The semi-structured interview and questionnaire were conducted after developing the LT4STHC framework, methodology and LT4ST index. Feedback is gained from verification approaches. The feedback is used to gather a group of sustainability, healthcare, or lean experts to engage in conversation regarding the proposed LT4STHC framework, methodology, and LT4ST index.

Each participant willing to participate in the SME verification interview, discussion, and questionnaire, received an overview document regarding this research (illustrated in Figure 48 in Appendix C). The overview document provides the SMEs with the aim and objectives of this research and the key literature used to develop the proposed LT4STHC framework, methodology, and LT4ST index. Also included in the overview document is an illustration of the LT4ST tool and the preliminary operationalisation of the LT4STHC framework. The questionnaire includes semi-structured close-ended as well as open-ended questions.

The key objective of the theoretical verification is to evaluate whether the suggested solution, the LT4STHC framework, methodology and LT4ST index, is suitable for its intended purpose and whether the research products present a reasonable theory. The semi-structured open-ended questions that were asked in the questionnaire were constructed around and guided by the following questions:

i. Will the requirement specifications of the developed framework, methodology, and index contribute to addressing the purpose and objectives?
ii. Will the framework, methodology, and index achieve their stated purpose?
iii. What are the key strengths and weaknesses of the framework, methodology, and index?

7.3 VERIFICATION FEEDBACK AND REFINEMENTS

The verification questionnaire consists of three sections. The first section included verification questions to demonstrate the literature used to develop the LT4STHC framework, methodology, and LT4ST index. This section aimed to verify that the framework presents a reasonable solution. The second section focused on verifying the LT4STHC framework, methodology, and LT4ST index development process. The third section focused on verifying the structure and methodology of the LT4STHC framework. The most significant comments and feedback from SMEs for each section are presented as suggestions, critiques, and comments to refine the LT4STHC framework, methodology, and LT4ST index. Table 36 presents the SMEs' feedback and rationale for their specific comments. This table depicts areas where their suggestions were incorporated into the LT4STHC framework, methodology, and LT4ST index.

Table 36: Verification feedback and refinements

Feedback Category	Feedback	Rationale	Refinement
Literature used to develop the LT4STHC framework, methodology, and LT4ST index	All SMEs agreed that the literature used provides a holistic rethink approach to sustainability transitions in healthcare.	Incorporating numerous aspects within a sustainability transition ensures the transition is holistically approached.	-
	Numerous SMEs highlighted that the identified aspects are satisfactory, but even more aspects of a sustainability transition could be considered.	Incorporating more aspects within a sustainability transition will add to the holistic perspective of the sustainability transition.	The elaboration of the aspects of the sustainability transition in relation to the healthcare system that could require support is suggested for future research purposes in Section 8.3.
	All the SMEs indicated that the literature used makes the framework very theoretical and complex to understand without an in-depth understanding of the key concepts.	The nature of the research requires a high level of theoretical rigour to substantiate the findings, which could make the framework challenging to understand.	Apply the framework to a case study to show a practical implementation example, as illustrated in Section 7.6.
	A few SMEs highlighted that the limitation of the framework is that it needs to address contextual specifics such as value chain and geographical or sectoral specifics.	It was stressed that socio-technical transitions in such contextual additions dictate the nature of a system in how it is developed, diffused, and adopted within a healthcare system.	It was highlighted as a limitation in Chapter 1.
	A significant number of SMEs agreed that the literature used is satisfactory. The SMEs are satisfied with the specific lean thinking approaches and principles used in the LT4ST tool. It was, however, suggested that even more lean thinking approaches and principles be incorporated for consideration.	A wide variety of lean thinking approaches and principles are covered and included to ensure that sufficient options are explored. The aspects pertaining to the transitions to sustainability approaches are also deemed satisfactory.	The expansion of the lean thinking approaches and principles is suggested for future work in Section 8.3.
Development approach used for the LT4STHC framework, methodology, and LT4ST index	All SMEs agreed that using the requirement specifications and approach for developing the framework is well-suited.	Utilising the requirement specifications and the "process management" approach to develop the framework is deemed satisfactory because this ensures that the research products are fit for their intended use.	-
	A significant number of SMEs agreed that the framework, methodology, and index are valuable for incorporating lean thinking to support sustainability transitions in healthcare.	It was highlighted that the Systems Engineering approach is deemed a well-structured approach to the research study. The requirement specifications and Process Management approach are adequate for this research study's intended purpose.	-

Feedback Category	Feedback	Rationale	Refinement
High-level structure and methodology of the LT4STHC framework, methodology, and LT4ST index	All SMEs agreed that the framework would achieve its stated purpose.	The framework is comprehensive, and its robustness will aid in the continuous improvement of healthcare systems.	-
	All SMEs agreed that the purpose of the LT4STHC framework, methodology, and LT4ST index is fit for its purpose and will achieve the aim of this research study. They also agreed that the phases in the framework methodology would achieve its stated goal.	-	-
	A significant number of SMEs agreed that the layout of the high-level structure and the methodology make the LT4STHC framework easy to understand. A few SMEs were, however, concerned with the high-level structure.	The framework could be easier to understand with clear explanations and definitions.	Clearer explanations were incorporated into the LT4STHC framework.
	SMEs highlighted that it is essential to mention the framework's aim in the operationalisation strategy.	An explicit aim for the framework, methodology, and index will ensure that the user is aware of its purpose before using it.	The framework's aim was incorporated in the introductory paragraph of Section 6.6.
	A significant number of SMEs highlighted that the framework is very detailed and elaborate.	The in-depth description and stepwise approach to the framework make it very user-friendly and practicable.	-
	SMEs suggested the incorporation of a type of gap analysis. The SWOT analysis was suggested.	The incorporation of a gap analysis will define the system in terms of its requirements and determines which steps need to be taken to meet them.	A gap analysis approach was incorporated into the LT4STHC framework as a SWOT analysis (refer to Section 6.4).
	SMEs highlighted that the framework should move away from definitive word use.	Using definitive words such as "cause" could be too restrictive, but the use of "contributing factors" is more flexible.	The framework was adapted to use more flexible wording that is less definitive.
General feedback	SMEs highlighted that it should be considered to demonstrate the LT4STHC framework.	The SMEs recommended that the framework be applied to a case study to demonstrate its usability and practicability.	A case study application is presented in Section 7.6.

7.4 VALIDATION

This section deals with the validation stage of the evaluation strategy for this research. As mentioned in Section 7.1, the validation step determines whether the framework, methodology and index are accurate presentations of the real world from the user's perspective and whether it is aligned with the user's needs.

Various types of validation approaches were considered, including subject matter interviews, questionnaires, practical application and implementation, and case studies (Ungerer, 2015). The validation of the LT4STHC framework, methodology, and LT4ST index is based on semi-structured interviews with SMEs in combination with a questionnaire and a practical case study application. The goal of the interviews, questionnaires and case study application is to validate the applicability, usability, and practicability of the framework, methodology, and index. The interviews, questionnaires, and case study application attempts to prove that the framework, methodology, and index are representative of a real-world phenomenon.

The validation of the LT4STHC framework, methodology and LT4ST index is executed by evaluating it along the following three dimensions:

i. The applicability of the framework, methodology and index to real-world cases is evaluated, i.e., to illustrate that the conceptual framework of the LT4STHC framework is representative of real-world phenomena;
ii. It is evaluated whether the framework, methodology and index can be put into practice; and
iii. The usability of the framework, methodology and index to the users is evaluated.

The validation questionnaire is illustrated in Figure 50 in Appendix C. The questionnaire consists of questions, each set focusing on validating a different dimension, as stated above. The questionnaire encompasses both close-ended questions and open-ended questions. The close-ended questions are guided by a five-point Likert scale, deemed a suitable approach for validating this study as it provides a scaled response approach. The five-point Likert scale enabled the calculations of a quantitative score of the extent to which the SMEs agree that the LT4STHC framework and the LT4ST tool are applicable, practicable, and usable. The open-ended questions allowed the participant to comment on the strengths, weaknesses and other aspects of the framework, methodology, and index. The validation questions and the dimensions each one targeted are summarised in Table 37 below. The results of the questionnaire the different SMEs completed are presented in the next section. Subsequently, the results are discussed, and conclusions are drawn regarding the framework, methodology, and index.

Table 37: Validation questions asked to SMEs

Dimension ID #	Dimension	Question/statement	Assessment method
1	Applicability	The requirement specifications (Chapter 3 of this document) and methodology effectively and adequately contribute to the research products.	**Five-point Likert Scale:** 5 - Strongly agree; 4 – Agree; 3 – Neutral; 2 – Disagree; 1 - Strongly disagree
2	Applicability	The research products (Chapter 4 of this document) sufficiently articulate the incorporation and orientation of the elements of lean thinking and sustainability transitions in healthcare.	
3	Applicability	The research products developed in this research support sustainability transitions in healthcare by using lean thinking.	
4	Usability	Considering the terminology and operability, the research products are easy to use and intuitive to understand.	
5	Usability	The user of the research products does not require a high level of experience or knowledge on using lean thinking to facilitate and support sustainability transitions in healthcare.	
6	Practicability	The research products could apply to any existing healthcare system.	
7	Strength	What do you view as some of the key strengths of the research products?	Open-ended questions
8	Weaknesses	What do you view as some of the key weaknesses of the research products?	
9	Weaknesses	Are you aware of any other system, research products, or framework with which this research products could be used?	
10	Weaknesses	Are there any literature sources that could have been overlooked, but should be considered for this research?	

7.5 VALIDATION RESULTS AND DISCUSSION

After the SME interviews and questionnaires were conducted, the results were analysed. Overall, the results were positive. The applicability, usability, and practicability of the LT4STHC framework, methodology, and LT4ST index were satisfactory and representative of a real-world system. The results of the questionnaires are illustrated in Table 38 and Figure 45 below.

Table 38: Questionnaire results

Question code from Table 37	Subject matter expert scores					
	SME 1	SME 2	SME 3	SME 4	SME 5	SME 6
Applicability						
1	4	5	4	3	4	5
2	4	4	4	4	4	4
3	4	3	4	5	4	4
Usability						
4	4	4	4	3	4	5
5	3	3	3	4	3	4
Practicability						
6	3	3	4	4	4	3

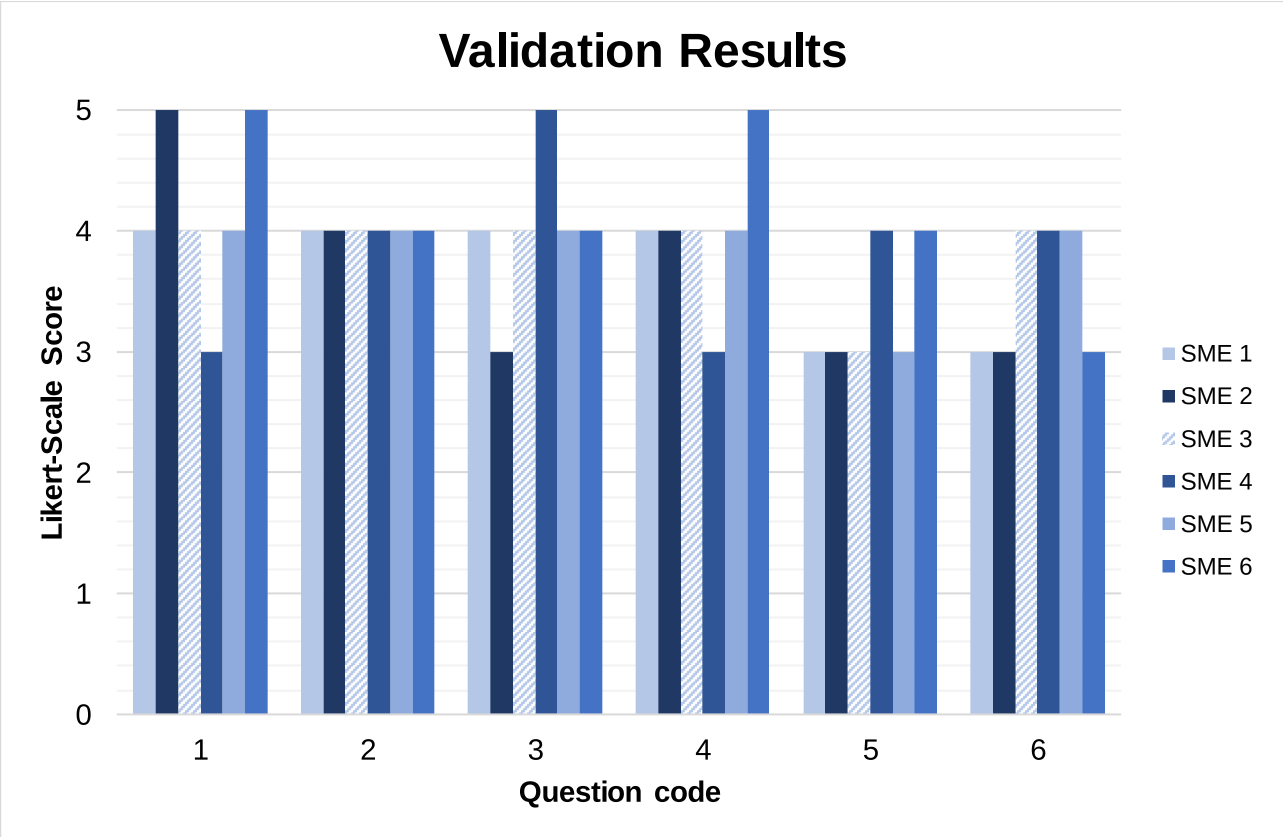


Figure 45: Graphical presentation of questionnaire results

7.5.1 APPLICABILITY

The SMEs' general feedback on the possible applicability of the LT4STHC framework, methodology, and LT4ST index was positive. All SMEs agreed that the research products sufficiently articulate the incorporation and orientation of elements of lean thinking within sustainability transitions in healthcare.

The SMEs mentioned that the LT4STHC framework, methodology, and LT4ST index could be applicable research products in the private healthcare sector but could be restricted in its use within the public healthcare sector. These concerns raised regarding the LT4STHC framework, methodology, and LT4ST index tool were considered. It was decided that expanding the framework, methodology, and index into the private and public healthcare sectors would be recommended for future research.

7.5.2 USABILITY

The SMEs' general feedback on the possible usability of the LT4STHC framework, methodology and LT4ST index was positive. The SMEs provided feedback on the usability of the framework, methodology, and index. In the feedback regarding the usability of the research products, it was evident that providing clear definitions and explanations of the terminology used would be beneficial. Including clear definitions and explanations of terminology would enable users with a wide variety of skills and knowledge to utilise the research products effectively. User input will be decreased, increasing efficiency, and reducing the time required to use the framework, methodology, and index. These factors were considered throughout the framework, methodology, and index development. However, it was suggested that the LT4STHC framework, methodology, and LT4ST index be even more simplified. This recommendation is suggested as future work in Chapter 8.

7.5.3 PRACTICABILITY

The SMEs had positive feedback regarding the possible practicability of the LT4STHC framework, methodology and LT4ST index. The SMEs highlighted that the framework and methodology are practicable, but the user would require some prior knowledge pertaining to the key areas of the framework that the user does. SMEs also highlighted that the framework is read-intensive and could require a high level of understanding to implement it efficiently.

7.6 A CASE STUDY APPLICATION ON A SOUTH AFRICAN HEALTHCARE SYSTEM

An illustrative case study was conducted to demonstrate the applicability, practicability, and usability of the LT4STHC framework in a real-world case. A case study is "*a strategy for doing research which involved an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence"* (Robson, 2002). This research aims to support sustainability transitions in healthcare through lean thinking implementation, which is contemporaneous. The case study further evaluates the practicability and usability of the developed framework and its operationalisation strategy.

<u>Case study selection:</u>

Mediclinic International is a diversified international private healthcare services group founded in South Africa in 1983. Mediclinic International takes a sustainable, long-term approach to business, putting patients at the heart of its operations and consistently aiming to deliver high-quality healthcare services. Mediclinic International is a socio-technical system that is complex and has multifunctional systems. Mediclinic International is a healthcare system that is designed to fulfil and satisfy the societal function of private healthcare provision. Lean is applicable in healthcare systems, as proven by literature. Mediclinic International is a healthcare system that experiences activities that require sustainability transitions. The 2022 Annual Report and 2022 Sustainable Development Report highlight Mediclinic International's need to implement sustainability transitions. It should be noted that the case study was done using only publically available data. Mediclinic was not involved in the provision of data or execution of the case study. The purpose of the case study is purely to validate the practicability, usability and applicability of the developed framework and methodology.

PHASE 1: HEALTH SYSTEM AND TRANSITION CONTEXTUALISATION

This phase involves investigating and analysing the healthcare system and the sustainability transition occurring within that healthcare system.

i. <u>Step 1.1 – Healthcare system demarcation:</u> understand the healthcare system

a. Make use of the "*Socio-technical Systems Theory*" [1] to understand the healthcare system.

Figure 46 below is a graphical illustration of Mediclinic as a socio-technical system. The socio-technical systems theory defines key aspects of the healthcare system, namely, the goals or metrics, the people, the infrastructure, the technology, the culture, and the procedures.

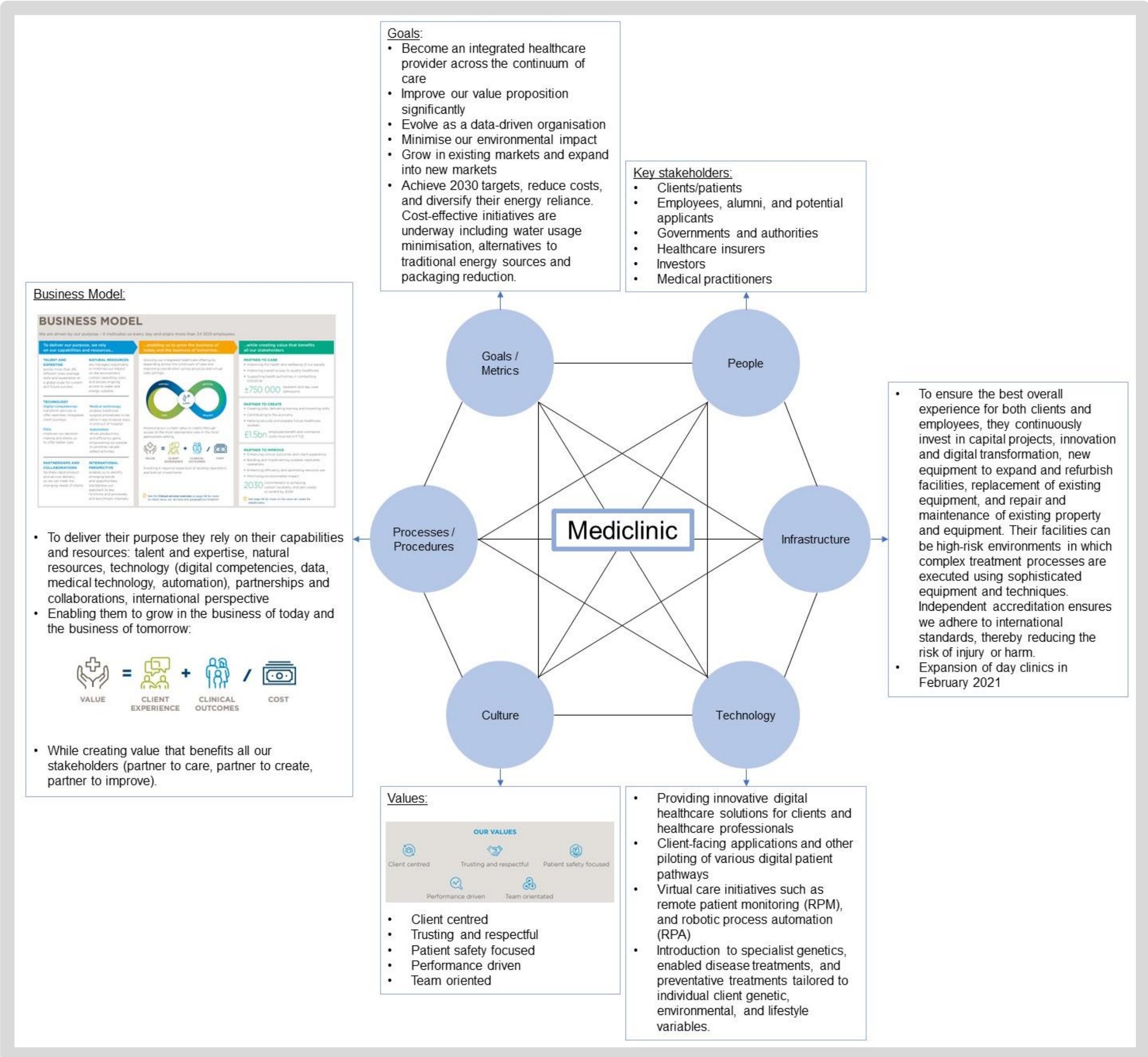


Figure 46: Mediclinic as a socio-technical system (Mediclinic International, 2022; Mediclinic International, 2022)

ii. Step 1.2 – Transition demarcation: understand the sustainability transition

a. Conduct an "As-Is Analysis" [2] to determine the current state of the sustainability transition.

Mediclinic International is experiencing material sustainability issues that are ranked in terms of their priority to address these issues. The specific material sustainability issues are discussed below, along with their priority ranking.

Mediclinic International's top business priorities are energy efficiency, reducing carbon emissions, waste management, employee engagement, employee wellness and safety, diversity and inclusion, client value proposition, and protection of information assets.

According to the heat map provided in Mediclinic's 2022 Annual Report, Mediclinic's attempt to minimise its environmental impact focuses on seven categories: climate change, environmental management systems, energy efficiency, carbon emissions, waste management, water management use, and biodiversity. Their attempts to protect biodiversity are regarded as successful. Their initiatives to address climate change, environmental management system, energy efficiency, and water use is performing relatively well. However, their carbon emissions and waste management projects require substantial focus.

Their "Conserve" initiatives include minimising their impact on climate change, becoming carbon neutral by 2030, having zero waste to landfill by 2030, using and reusing their water resources sustainably, and improving their environmental management system. In 2021 Mediclinic Southern Africa signed an agreement to the total value of £110m to procure renewable energy.

For this case study, the two categories that require the greatest focus will be used as the identified transition to sustainability. These categories are:

1. *Carbon emissions – "Becoming carbon neutral by 2030" (Nr 4 on heat map)*
2. *Waste management – "Having zero waste to landfill by 2030" (Nr 5 on heat map)*

Their progress in 2022 in terms of the two categories mentioned above was its centralisation of their environmental data management system. They reached an agreement with the Energy Exchange of Southern Africa to initially procure renewable energy for five facilities in Southern Africa. They finalised their roadmaps to become carbon neutral and have zero waste to landfill in Southern Africa (Mediclinic International, 2022)*.*

Mediclinic Southern Africa's regional information for "becoming carbon neutral by 2030":

Table 39: Mediclinic Southern Africa total carbon emissions 2020 vs 2021 (Mediclinic International, 2022; Mediclinic International, 2022)

	Total Carbon emissions of Mediclinic Southern Africa (tons)	
	2020	***2021***
Scope 1 emissions *(Direct emissions from Mediclinic-owned or controlled equipment, air-conditioning and refrigeration gas refills, anaesthetic and other gas consumption, emergency response vehicles, and fleet and pool vehicles)*	*22 083*	*22 215 (Increase due to diesel consumption on account of load shedding, anaesthetic gases used in theatre and use of mobile fuel)*
Scope 2 emissions *(Indirect emissions from purchased electricity)*	*151 053*	*154 982 (Scope 2 emissions -purchased electricity- increased because of an increase in the emission factor (conversion of kWh to CO_2e)*

	Total Carbon emissions of Mediclinic Southern Africa (tons)	
	2020	**2021**
		even though total electricity usage decreased year on year)
Scope 3 emissions *(Indirect emissions in the supply chain, business travel activities, employee commuting, upstream and downstream third-party distribution, office paper consumption, electricity transmission, and distribution losses and waste)*	*39 576*	*47 115 (Increase due to resumption of business travel and upstream transportation)*
Non-Kyoto Protocol emissions *(GHG emissions such as from Freon, used in air-conditioning and refrigerant equipment. Emission data were converted into a carbon dioxide equivalent ('CO_2e'))*	*3 180*	*2 292*
Total Scope 1 & 2 **CO_2e**	*173 136*	*177 197*
Total Scope 1 & 2 **CO_2e / Full-time Equivalent ('FTE')**	*10.96*	*9.32*

As illustrated in Table 39, the total carbon emissions indicate that Mediclinic Southern Africa experienced an increase in their Scope 1, 2 and 3 CO_2e**.**

Table 40: Mediclinic Southern Africa's direct and indirect energy consumption 2020 vs 2021 (Mediclinic International, 2022; Mediclinic International, 2022)

		Direct and indirect energy consumption (GJ)	
		2020	**2021**
Direct energy purchased		103 132	117 940 (Increase due to higher diesel consumption on account of load shedding as well as the use of mobile fuel and aviation fuel)
Direct energy produced		1 437	1 557
Indirect energy consumed		548 249	542 950
Energy consumption	**Total**	652 818	662 447
	Per FTE	35.05	34.84

The direct and indirect energy consumption, as illustrated in Table 40, of Mediclinic Southern Africa still requires focus. Their direct purchased energy has increased by 14 808 GJ between 2020 and 2021.

Further regional information pertaining to "becoming carbon neutral by 2030":

I. An agreement was reached to purchase renewable energy for five facilities.
II. Renewable energy is produced through photovoltaic (PV) systems (New PV installations at five hospitals in Southern Africa, increasing the total to 18).
III. Solar panels for water heating were installed.
IV. Supervisory control and data acquisition systems to monitor consumption were installed.
V. Completed hospital audits and agreed to potential savings.
VI. Energy-efficient practices were implemented.

Mediclinic Southern Africa's regional information for "having zero waste to landfill by 2030":

Table 41: Mediclinic Southern Africa waste management 2020 vs 2022 (Mediclinic International, 2022; Mediclinic International, 2022)

	Waste Management of MC Southern Africa	
	2020	***2021***
Total waste (tons)	*7 892*	*8 363* (Increase in waste due to increased HCRW on account of the COVID-19 pandemic, returning to business as usual and inclusion of additional waste sources, such as the recovery of organic waste (not previously reported on)
Total waste diverted from landfill (tons)	*1 360*	*1588*
Waste diverted from landfill as a percentage of total waste (%)	*13.6*	*19*
Total water usage (kL)	*1 029 058*	*1 086 815*

As illustrated in Table 41, the waste management of Mediclinic Southern Africa still requires focus. The total waste has increased by 471 tons between 2020 and 2021.

Further regional information pertaining to "having zero waste to landfill by 2030":

I. Waste management tenders to incorporate new requirements
II. Healthcare risk waste (HCRW) is transported and treated by licensed companies using autoclave or electrothermal deactivation.
III. Incinerated anatomical waste
IV. Donated redundant furniture and equipment
V. Recovered cooking oil for biodiesel
VI. Newster technology (Newster sterilisers use patented frictional heat treatment technology for the sustainable processing of HCRW) implemented at one hospital.

b. Conduct a "To-Be Analysis" [3] to determine the future state, describing the desired output and goals of the sustainability transition.

<u>Strategic Goals for Financial Year (FY) 2023 - 2026:</u>

Mediclinic aims to:

I. Become an integrated healthcare provider across the continuum of care.
II. Minimise their environmental impact and improve their value proposition (conserve).
III. Grow in existing markets and expand into new markets.
IV. Build stakeholder trust by improving their value proposition and transforming their services and client engagement through innovation and digitalisation (connect).
V. Being an ethical and responsible corporate citizen by improving their value proposition, transforming their services and client engagement through innovation and digitalisation, evolving as a data-driven organisation (comply).
VI. Achieve qualitative targets to reduce waste and increase recycling, including creating uniform disposal concepts, optimising waste management with new suppliers through circular economies, changing behaviour and conducting waste audits at facilities with high HCRW.
VII. Finalise action plans to reduce anaesthetic gases and N_2O emissions in Southern Africa (Feasibility study initiated, with results expected in the first quarter of FY23. Pilot project at two hospitals planned for FY23 pending outcome of the feasibility study).

VIII. MC's Group Sustainable Development Strategy recognises the value of circular economies to reduce waste. Their procurement and environmental teams engage with suppliers on feasibility (reduce waste at the source with Johnson & Johnson MedTech). This initiative focuses on single-use medical devices and packaging not being recycled. Feasibility studies to determine stakeholder readiness will be scalable to include single-use medical devices and products from other suppliers.

c. Complete a "*Gap Analysis*" [4] to determine where the system is within the sustainability transition and where it would like to be.

The SWOT analysis was chosen as the appropriate gap analysis, and SMEs suggested it.

Table 42: Mediclinic strengths

Strengths
The strengths of Mediclinic investigate its business's key aspects, which gives it a competitive advantage in the market. Some essential factors in a brand's strengths include its financial position, experienced workforce, product uniqueness & intangible assets like brand value. *The strengths of Mediclinic are:* *i. Clinical staff that are highly trained, skilled, and knowledgeable* *ii. Mediclinic International have multiple facilities outside of South Africa as well.* *iii. Mediclinic International experience substantial revenue and profit growth.* *iv. Mediclinic International works with a wide range of design service consultancies and contractors within and outside South Africa.* *v. Mediclinic Southern Africa has over 12 000 employees.* *vi. Mediclinic International has a strong market leadership position in the Healthcare Facilities industry. It has helped the company to scale new product successes rapidly.* *vii. Mediclinic International has an extensive dealer and associates' network that helps deliver efficient services to customers but also helps manage competitive challenges in the Healthcare Facilities industry.* *viii. Mediclinic International provides exhaustive product mix options to its customers. It helps the company cater to various customer segments in the Healthcare Facilities industry.* *ix. Even though Mediclinic International is facing downward pressure on profitability compared to competitors, it is still raising profit margins.* *x. Mediclinic International's extensive product offerings have helped the company to penetrate different customer segments in the Healthcare Facilities segment. It has also helped the organisation diversify its revenue streams.* *xi. Over the years, Mediclinic International has ventured into various businesses outside the Healthcare sector. This expansion has enabled the company to develop a diversified revenue stream beyond the healthcare sector and Healthcare Facilities segment.*

Table 43: Mediclinic weaknesses

Weaknesses
The weaknesses of a brand are certain aspects of the business that it can improve on to increase its position further. Weaknesses can be defined as attributes that the company lacks or in which the competitors perform better. The weaknesses in Mediclinic are: *i. Investments in research and development are insufficient.* *ii. The development of new products and services is frequently required to maintain their competitive advantage.* *iii. High turnover of employees at the lower levels is also a concern for Mediclinic International. It can result in the payment of higher salaries to maintain the talent within the firm.* *iv. Low investments into Mediclinic International's customer-oriented services can lead to competitors gaining an advantage soon. Mediclinic International needs to increase investment into research and development, especially in customer services-oriented applications.* *v. Competitiveness in the Healthcare Facilities industry is putting downward pressure on profitability. A starting guide to managing this situation for the company name is – objectively assessing the present value propositions of the various products.* *vi. Niche markets and local monopolies that companies such as Mediclinic International can exploit are decreasing. The customer network that Mediclinic International has promoted is providing decreasing gross and operating margins. The lower profitability could put pressure on Mediclinic International's financial statements in the future. Less effective.* *vii. There is a high cost in replacing existing experts within Mediclinic International. Few employees are responsible for Mediclinic International's knowledge base and replacing them will be extremely difficult in the present conditions.*

Table 44: Mediclinic opportunities

Opportunities
The opportunities for any brand can include areas of improvement to increase its business. A brand's opportunities can lie in geographic expansion, product improvements, and better communication. The opportunities of Mediclinic are: *i. Increasing stringency in rules, the government announced a landmark agreement that sets a new quality benchmark between a private healthcare provider and a health insurer.* *ii. Mediclinic International could reach emerging economies through tie-ups and associations.* *iii. Increasing awareness of healthcare solutions.* *iv. As customers must migrate from unorganised operators in the Healthcare industry to licensed players, it will provide Mediclinic International with an opportunity to penetrate the entry-level market with a no-frills offering.* *v. Increasing government regulations make it difficult for unorganised players to operate in the Healthcare Facilities industry. This can provide Mediclinic International with an opportunity to increase its customer base.* *vi. Lowering the cost of new product launches through third-party retail partners and dedicated social networks. Mediclinic International can use the emerging trend to start small before scaling up after the initial success of a new product.* *vii. Driven by rising disposable incomes, easy access to information, and fast adoption of technological products, customers are more willing to experiment with new products in the market. Mediclinic International must carefully monitor broader trends within the Healthcare Facilities industry and the wider Healthcare sector.* *viii. The low inflation rate brings more stability to the market, enabling credit at a lower interest rate to the customers of Mediclinic International. The lower interest rate could increase the consumption of Mediclinic International products.* *ix. Collaboration with local players can also provide growth opportunities for Mediclinic International in international markets. The local players have local expertise, while Mediclinic International can bring global processes and execution expertise to the negotiating table.*

Table 45: Mediclinic threats

Threats
The threats for any business can be factors which can negatively impact its business. Some factors like increased competitor activity, changing government policies, and alternate products or services can be threats. The threats for Mediclinic are: *i. The existence of small private clinics located at convenient distances can result in patients not utilising the services of Mediclinic.* *ii. Changes in insurance plans or government policies imply that Mediclinic needs to adapt to align with these plans and policies.* *iii. Changing political environment with US and China trade war, Brexit impacting European Union, and overall instability in the middle east can impact Mediclinic International's business in the local and international markets.* *iv. Trade relations between US and China can affect Mediclinic International's growth plans, leading to a full-scale trade war that can hamper the potential of Mediclinic International to expand operations in China.* *v. Mediclinic International is still the leader in product innovation in the Healthcare Facilities segment. However, it is facing stiff challenges from international and local competitors.* *vi. The baby boomers are retiring, and the new generation finds it hard to replace the purchasing power of this group. This can lead to higher profits in the short run for Mediclinic International but reduce margins over the long run as young people are less brand loyal and more open to experimentation.* *vii. The biggest challenge for Mediclinic International and other players in the industry is the increasing commoditisation of the products in the healthcare industry.* *viii. As WTO regulations and laws are difficult to enforce in various markets, legal procedures have become expensive and lengthy processes. It can lead to less investment into emerging markets by Mediclinic International, thus resulting in slower growth.*

iii. Step 1.3 – Aim and purpose: determine the aim and purpose of the sustainability transition in the healthcare system

a. Use the results from the previous steps to determine the combined aim and purpose of the sustainability transition within the healthcare system.

A sound strategy supports Mediclinic's commitment to carbon-neutral status. Emission reduction activities help save costs, secure the energy supply, and leave a healthy planet for prosperity. Rising electricity costs are an incentive to reduce consumption by investing in energy-efficient equipment and renewable energy sources. The boundary for carbon neutrality covers Scope 1 and 2 emissions. Mediclinic can eliminate Scope 2 emissions by purchasing 100% renewable energy, but it must also offset direct carbon emissions and reconsider energy consumption and emissions from power generation. Mediclinic is working to reduce the use of harmful anaesthetic gases in Southern Africa. Control strategies include elimination, substitution, engineering control (CO_2 absorbers, gas capturing technologies), administrative controls, and education and awareness. Electricity is the largest contributor to Mediclinic's carbon footprint. Healthcare facilities require significant energy to utilise medical equipment and operate air-filtration and -conditioning units continuously. Improved operational efficiency of technical installations, the introduction of various new energy-efficient and renewable technologies, and changes in employee behaviour are essential for reducing energy use. Mediclinic's Group Waste Management Policy outlines its objectives: refuse, reuse, reduce, recycle, and recover. Mediclinic follows stringent protocols to ensure waste management within the Group complies with all applicable legislation and regulations. During the reporting period, no incidents at *their facilities or offices led to significant spills. Mediclinic's Group Sustainable Development Strategy recognises the value of circular economies to reduce waste, and their procurement and environmental teams are engaging with suppliers on feasibility.*

PHASE 2: HINDRANCE CONTEXTUALISATION

This phase consists of identifying the hindrance of the sustainability transition, the cause of the hindrance, and the phase of the sustainability transition the hindrance occurs. Hindrance is defined as something that provides resistance, delay, or obstruction to the progress of the sustainability transition that is occurring in the healthcare system.

iv. Step 2.1 – Hindrance demarcation: identify what contributes to the lack of progress in the sustainability transition.

  a. Identify the hindrance contributing to the lack of progress in the sustainability transition. The author developed the Hindrance identification tool [5] for this purpose.

The sustainability transitions of "becoming carbon neutral by 2030" and "zero waste to landfill by 2030" are landscape tensions (increased sustainability) and transformation pathways (to a more sustainable state).

According to the "Hindrance identification tool", possible contributing factors hindering the sustainability transitions are the standardisation of practices/routines, provision of resources, imposition of a new functioning (sustainability), and radical change without a gradual introduction to the new pathways. The goal is for Mediclinic to become more sustainable, create more value, eliminate waste, and become carbon neutral by 2030.

v. Step 2.2 – Hindrance cause: identify and determine the contributing factors of the hindrance.

  a. Conduct a "*Root Cause Analysis*" [6] to discover why the aspect or phase in the sustainability transition is lacking, thus not allowing the sustainability transition to progress to the next phase.

RCA steps to identify the contributing factors of the hindrance:

1. Categorise the type of problem which occurs. Problems can be material-based problems, people-based problems, organisational-based problems. Material-based problems occur when a specific material item has failed in some way, such as when a piece of machinery malfunctions. People-based problems occur when human error is the cause of the current issue. Often a people-based problem will lead to a material problem, e.g., a piece of machinery fails because an employee neglected to perform regular maintenance. An organisational-based problem stems from a company process or policy that causes an issue to occur. Keeping with our current example, maintenance on the malfunctioning piece of machinery occurred because the company process for assigning maintenance duties was faulty.

Mediclinic's sustainability transition combines a people-based and organisational-based problem because human error and company processes are the leading cause of grand-sustainability challenges.

2. Collect sufficient data by asking questions such as: How long has this problem existed in our company? What impact does it have on daily operations?

3. Identify the associated causal factors – An action or lack of action that caused an Incident or made the incident worse, such as an increase in ineffective resource use and healthcare waste.

4. Conclude why the problem occurred.

5. Implement the necessary changes by asking questions such as: What can be done to ensure this problem does not repeat itself? Is a new process required?

vi. Step 2.3 – Hindrance phase: identify and determine in which aspect or phase of the sustainability transition the hindrance is occurring.

a. Determine the transition phase in which the problem occurs, i.e., pre-development, take-off, acceleration, and stabilisation, using the results of the "*Root Cause Analysis"* as conducted in the previous step.

As previously mentioned, the sustainability transitions are "becoming carbon neutral by 2030" and "zero waste to landfill by 2030". Identifying this as landscape tensions and transformation pathways, problems can occur in any phase of the sustainability transition due to the transition itself being a landscape tension.

PHASE 3: LEAN AND HINDRANCE INTERRELATION

This phase determines which lean thinking approach or principle could support the identified hindrance.

vii. Step 3.1 – Lean identification: identify lean approaches or principles that could address the hindrance that is causing the sustainability transition in healthcare not to progress.

a. Utilise the "*LT4ST tool*" [7] to identify which lean thinking approach or principle could be used to support the identified hindrance aspect. The LT4STHC framework will be the approach to assist in determining the required lean thinking approaches and principles that can be implemented to ensure that the sustainability transition has no hindrance and progresses without any disruptions.

According to the LT4ST tool, because we are dealing with a landscape tension and a transformation pathway, we will be utilising Lean4Tension as illustrated in Table 49 in Appendix B and Lean4Pathways in Table 58 *in Appendix B.*

Depending on the level of required support of the lean thinking approach or principles as illustrated in Figure 27 in Section 5.3, the appropriate lean thinking approach or principle could be identified that needs to be implemented to support the sustainability transitions of "becoming carbon neutral by 2030" and "zero waste to landfill by 2030".

Seeing that sustainability is a concept that needs to be incorporated on a system-wide level, it is pivotal for the following perspectives approached when supporting the sustainability transition.

TMS - Achieve sustainable vision and purpose of an SBM at a large scale. Change dominant cultures and practices to the societal level.

TMT - Set networks and collaborations towards sustainability with key stakeholders identified in an SBM. Change the dominant operational structure of value creation along the value chain at the sector level.

TMO - Establish an SBM vision and purpose and start implementing sustainable-related practices. Change dominant practices at the firm level.

TMR - Monitoring and evaluating the current situation in all three levels and the interrelation or misfit.

The question that needs to be asked is: What could be implemented? It is identified that a lean thinking approach or principle should have the APPS perspective. APPS identifies that the lean thinking approach or principle could assist in answering the question: "What should happen?" This perspective will also be considered in the lean thinking identification. Only lean thinking approaches and principles which apply to all five identified perspectives will be considered.

As this sustainability transition was identified as a landscape tension and a transformation pathway, Lean4Tension's and Lean4Pathways's practical lean thinking approaches and principles will be considered.

According to Tables 49 and 58, *appropriate lean thinking approaches and principles that could be implemented to support the sustainability transition of "zero waste to landfill in 2030" are:*

<u>4P MODEL OF THE TOYOTA WAY & LIKER'S LEAN MODEL:</u>

PROBLEM-SOLVING: continuous improvement and learning

I. Continual organisational learning through Kaizen (continuous improvement)
II. Directly observe the location and its condition to understand and solve any problems faster and more effectively - Genchi Genbutso (TechTarget, 2018).
III. Make decisions carefully by consensus, thoroughly considering options and rapid implementation.

PEOPLE & PARTNERS: respect, challenge, and grow

I. Grow leaders who live the lean philosophy.
II. Respect, develop, and challenge the organisation's people and teams.
III. Respect, challenge, and help the organisation's suppliers.

PHILOSOPHY: long-term thinking

I. Base management decisions on a long-term philosophy, even at the expense of short-term financial goals

<u>LEAN PRACTICES & APPROACHES:</u>

I. Mindset & Attitude – implement methods and practices with a long-term commitment towards lean green practices. Ensure that the implementation plan is understood and communicated.
II. Leadership & Management – Ensure a continual long-term lean investment in the employees and maintain their willingness towards the promotion of lean culture by ensuring that the leaders are committed as well. Ensure that people with the required skills are in the correct positions for a successful lean journey. Ensure that the organisation's leaders have an in-depth understanding of the lean journey.
III. Employee Involvement – Ensure that employees develop by actively involving them during the lean journey.
IV. Ensure the lean implementation has a permanent and devoted commitment, and ensure the employees are willing to change. Ensure that employees develop by actively involving them during the lean journey.

V. Tools & Techniques – Implement tools and techniques to increase the competitive advantage and the business' performance. The use of tools increases sustainability without decreasing ecologically based efficiency.

VI. Six Sigma – Ensure the reduction in defects in the services.

LEAN PRINCIPLES:

I. Reducing/Eliminating activities that do not add value
II. Reducing uncertainty
III. Focus on customer requirements
IV. Reduce cycle time
V. Simplifying the process
VI. Increase production flexibility
VII. Increase process transparency
VIII. Controlling the entire process
IX. Improving the process continuously
X. Gathering information about competitors
XI. Reduction of raw materials
XII. Efficient allocation of human resources

PHASE 4: LEAN IMPLEMENTATION

This phase consists of determining a plan of action for implementing the identified lean thinking approach or principle that could support the aspect or phase in the sustainability transition in relation to healthcare that requires attention for the sustainability transition to flow.

viii. Step 4.1 – Support sustainability transition progression: determine a plan of action

a. Discuss and determine why and how the identified lean thinking approach or principle (as determined by using the "*LT4ST tool"*) can support the identified hindrance, which will assist in ensuring the success in the progress of a sustainability transition in the healthcare system.

4P MODEL OF THE TOYOTA WAY & LIKER'S LEAN MODEL:

PROBLEM-SOLVING: continuous improvement and learning

Continuous improvement increases sustainability as it aims to harness ongoing performance improvement. Directly going to the facilities where the sustainability transition occurs will enable the organisation to see the sustainability transition in action physically, and visually identifying where problems occur. Make decisions carefully by consensus, thoroughly considering options and rapid implementation. This could lead to increased sustainability as all options regarding the optimal output in terms of sustainability goals could be considered.

PEOPLE & PARTNERS: respect, challenge, and grow

Developing leaders who live the lean philosophy can increase sustainability because lean thinking and sustainability have the same objective and targets. Developing the leaders ensures that the organisation's governance body is fully aware and equipped with the necessary knowledge to maintain a lean sustainable journey.

Respect, develop, and challenge the employees and teams regarding the organisation's sustainability goals. Respect, challenge, and help the organisation's suppliers regarding the organisation's sustainability goals.

PHILOSOPHY: long-term thinking

Base management decisions on a long-term sustainability philosophy, even at the expense of short-term financial goals.

LEAN PRACTICES & APPROACHES:

Mindset and attitude could lead to increased sustainability if the lean implementation plan is understood and communicated. Implementing methods and practices with a long-term commitment to lean green practices is directly related to increased sustainability.

Leaders and management could lead to increased sustainability if the employees invest in the continual long-term lean journey. Maintaining the employee's willingness to adopt a lean culture can increase sustainability by eliminating waste, improving the whole process, and reducing the negative impact of the healthcare industry. Ensuring that people with the necessary skills are appointed to the correct position increases sustainability by efficiently allocating sufficient human resources.

Employee involvement could lead to increased sustainability if the employee's put effort into lean implementation. The employees must commit to the sustainability transition journey permanently and devotedly.

Tools and technique implementation could increase sustainability by increasing the competitive advantage while increasing the business performance and decreasing ecologically based efficiency.

Six Sigma could lead to increased sustainability by decreasing defects within the healthcare system.

LEAN PRINCIPLES:

All the lean principles can be implemented throughout the entire healthcare system. The system-wide implementation of the 12 lean principles increases sustainability as all 12 principles have a direct positive effect on sustainability (as identified and illustrated in Table 10 in Sub-section 3.4.3).

CASE STUDY CONCLUSION

From the case study, it is observed that the framework achieves its intended goal of supporting sustainability transitions in healthcare by implementing lean thinking approaches and principles. The case study also demonstrates that the framework applies to current societal systems, i.e., healthcare systems. The operationalisation strategy gives the framework practical utility and enables the user to apply the framework in a real-world context. The case study also demonstrates that the framework is usable given the strategy's guidelines and the successful demonstration of the case study presented above.

7.7 CHAPTER 7: CONCLUSION

The aim of this chapter was to evaluate the developed LT4STHC framework, methodology, and LT4ST index. The verification included the evaluation of the requirement specifications and theoretical verification through subject matter experts. The subject matter expert interviews, questionnaires, and a case study were conducted to validate the applicability, practicability, and usability of the LT4STHC framework, methodology and LT4ST index to deduce the applicability and validity of the research products.

CHAPTER 8: CONCLUSION AND FUTURE WORK

Chapter 8, the last chapter in this study, concludes the research. In this final chapter, a summary of the research is presented, and the attainment of the research objectives is assessed and discussed. Recommendations for future work are presented to fulfil the RO5 (refer to Section 1.3).

8.1 RESEARCH SUMMARY

Modern societal systems face the global sustainability challenge, increasing the need for more sustainable configurations. Lean thinking demonstrates the potential to contribute to grand sustainability visions of modern societal systems, in this case, healthcare systems, by supporting the transition to more sustainable states.

The research aimed to contribute toward modern healthcare systems' movement to more sustainable states by implementing lean thinking to support sustainability transitions. The primary objective of the research was to investigate the extent to which literature has analysed the implementation of lean thinking into sustainability transitions to support the flow of the transition in healthcare systems. The literature analysis found that the intended integration of lean thinking to support sustainability transitions in healthcare was lacking. The research presented a framework, methodology, and index in combination with a case study application of the developed research products, enabling the user to utilise and apply the framework in a real-life phenomenon. Table 46, below, presents an assessment of the research objectives and their fulfilment as presented in this thesis.

Table 46: A review of the achievement of the research objectives

Research Objective (RO)	Sub-objective	Summary and evaluation of objectives attained	Section Achieved
RO1: Review and analyse literature about sustainability and socio-technical transitions, healthcare, lean thinking, sustainable healthcare, lean healthcare to:	RO1.1: Identify the lean challenges being faced in healthcare.	A review of the literature regarding lean thinking in South African healthcare was presented in fulfilment of Research Objective 1.1. Lean thinking literature was presented with a review of challenges experienced in healthcare. Examples of lean challenges in healthcare are prolonged waiting time due to a lack of human resources, adverse events, poor hygiene and infection control measures, increased litigation because of avoidable errors, and a shortage of resources in medicine and equipment.	Chapter 2, Section 2.1
	RO1.2: Identify the extent to which lean thinking has been incorporated into healthcare.	Literature on incorporating lean thinking into healthcare was presented in fulfilment of Research Objective 1.2. The literature identified that lean thinking has extensively been incorporated into the manufacturing sector, but lean thinking is relatively new regarding its implementation in healthcare. However, lean implementation in healthcare has increasingly become more popular due to the process improvement, value creation, and waste elimination characteristics of lean. These characteristics of lean thinking in healthcare assist in improving the quality of care that patients receive while simultaneously increasing the efficiency of the healthcare system.	Chapter 3, Section 3.2
	RO1.3: Identify the extent to which sustainability transitions have been incorporated into healthcare.	A review of literature about incorporating sustainability transitions in healthcare was presented in fulfilment of Research Objective 1.3. It was identified that the literature regarding sustainability transitions in healthcare needs to be expanded. Sustainable healthcare systems are a growing topic in research and policy trends. However, the transition towards sustainable healthcare entails complex issues. There is a need to acquire new knowledge and skills regarding sustainability transitions in healthcare. Due to the complexity of sustainability transitions in healthcare, sustainability goals should be integrated into their proposition, creation, and value capture. As healthcare is deemed a socio-technical system, it is essential to ensure a holistic approach to transition toward more sustainable states.	Chapter 2, Section 2.4 & Chapter 3, Section 3.3
	RO1.4: Identify the extent to which lean thinking has and can contribute towards sustainability transitions in healthcare.	Implementing lean thinking to support sustainability transitions in healthcare is a novel approach. A literature review about incorporating lean thinking to support sustainability transitions in healthcare was presented in fulfilment of Research Objective 1.4. The gap analysis of these focus areas identified the lack of lean implementation in sustainability transitions in healthcare. After this evaluation, it was determined that lean thinking could support sustainability transitions in healthcare since lean thinking and sustainability are similar in terms of their objectives and operations for value creation and waste elimination.	Chapter 2, Section 2.1 & Chapter 3

Research Objective (RO)	Sub-objective	Summary and evaluation of objectives attained	Section Achieved
RO2: Develop a set of requirement specifications that guides the development of research products that facilitate and supports lean thinking in sustainable transitions in healthcare.	-	Informed by the literature from Chapters 2 and 3, the requirement specifications to which the proposed research products should adhere were established in fulfilment of Research Objective 2. These requirement specifications were developed to ensure that the research products respond to the stated problem and will achieve the aim of this research study. The requirement specifications were provided in terms of functional requirements, user requirements, design restrictions, attention points, and boundary conditions.	Chapter 4, Section 4.2
RO3: Determine a set of intervention strategies that can assist in accomplishing the determined requirement specifications.	-	A functional analysis was conducted in fulfilment of Research Objective 3. This analysis identified suitable intervention strategies that could assist in achieving the developed requirement specifications. It was identified that seven different socio-technical transition approaches are deemed viable for this research study. These approaches pertain to different aspects of a sustainability transition to ensure that a lean implementation can support various aspects of the sustainability transition in healthcare. These approaches are: i. Forces and conditions for transitional change in synthesis with MLP to understand and identify how lean could contribute to supporting landscape tensions, regime stress, and niche pressure; ii. Transition and transformational failures to understand and identify how lean thinking can support various failure types during a sustainability transition; iii. ISA to understand and identify how lean thinking can support any weaknesses that are evident within the sustainability transition; iv. SNM to understand and identify how lean thinking can support the introduction of new sustainable technologies; v. Transition Management to understand and identify whether the identified lean thinking approaches and principles could be used in a strategic, tactical, operational, or reflexive manner; vi. RST to understand and identify how lean thinking can support progress, stability, and adaptability during a sustainability transition; and vii. Transition pathways to understand and identify how lean thinking can support different transition pathways that can make up a sustainability transition in healthcare.	Chapter 5
RO4: Develop research products to facilitate lean thinking in sustainable transitions in healthcare, with an	-	The LT4STHC framework, methodology and LT4ST index are proposed as the designed result of implementing lean thinking to support sustainability transitions in healthcare. The framework, methodology, and index were presented in fulfilment of Research Objective 4. The framework, methodology, and index are an integrated	Chapter 6

Research Objective (RO)	Sub-objective	Summary and evaluation of objectives attained	Section Achieved
operationalisation strategy of the research products. The operationalisation strategy will make use of a synthesised index that indicates which lean thinking approach or principle could support the respective sustainability transitions.		approach that considers the literature from Chapters 2 and 3, the requirement specifications of Chapter 4, and the intervention strategies of Chapter 5. The LT4STHC framework, methodology and LT4ST tool consist of a high-level structure, a methodology that outlines the conceptual framework of the LT4STHC framework, and the operationalisation of the framework, methodology, and index.	
RO5: Evaluate the developed research products by conducting verification and validation to evaluate the theoretical correctness, practicability, usability, applicability, and whether the research products are fit for their intended purpose as stipulated by the requirement specifications.	-	The evaluation process comprised of a verification and validation process was presented in fulfilment of Research Objective 5. The framework, methodology, and index were evaluated to ascertain that the appropriate research products were developed for their intended purpose. The framework, methodology, and index exhibited theoretical correctness and were consistent with existing theory and literature about lean thinking and sustainability transitions in healthcare. The evaluation process was conducted with the assistance of SMEs in the fields of sustainability, lean and healthcare to ensure comprehensiveness. The SMEs provided feedback through semi-structured interviews and questionnaires. The feedback was categorised and incorporated into the framework, methodology, and index for refinement. The LT4STHC framework, methodology, and LT4ST index were evaluated against the requirement specifications for its development to ensure that the research products' solution was consistent with the identified gap in the literature.	Chapter 7 & 8

8.2 RESEARCH CONTRIBUTION

The main contribution of this research is the LT4STHC framework and the LT4ST tool, which are presented in Chapter 6. The framework, methodology, and index present the basis on which the implementation of lean thinking can support sustainability transitions in healthcare. As previously discussed in the literature analysis in Chapter 4, the integration of lean thinking within sustainability transitions in healthcare was lacking. The developed framework, methodology, and index are intended to fill this research gap. Furthermore, it is observed that numerous research studies conducted on socio-technical transitions and lean thinking implementation to support such transitions are limited and novel. The limited research reflects the evident harmonious nature of lean thinking to support sustainability transitions in healthcare. This research, therefore, aimed to further contribute to the implementation of lean thinking to support sustainability transitions in healthcare through:

i. Simplifying the concept of lean thinking for it to be able to support sustainability transitions in healthcare;
ii. Making the integration of lean thinking into sustainability transitions practical and applicable to modern societal systems; and
iii. Providing a premise for developing new perspectives and approaches towards the facilitation of socio-technical transitions in the form of sustainability transitions in healthcare.

8.3 LIMITATIONS

All relevant topics could not be explored in depth. For instance, the transition approaches could be expanded to understand more components of a sustainability transition. The lean thinking approaches and principles were selected based on the literature evidence of successful implementation in the healthcare industry. These lean thinking approaches and principles could be expanded to allow for a broader perspective of lean thinking to be incorporated.

The evaluation of the real-world application of the LT4STHC framework, methodology and LT4ST index is limited to the case study that was applied. A case study which would have granted real feedback and results in a real-world setting would have been more beneficial. The SME verification interviews and questionnaires articulated the framework, methodology and index relevance and practicability. The SMEs agreed that the developed LT4STHC framework, methodology, and index are fit for their intended purpose and will accomplish their aim of implementing lean thinking approaches and principles to support sustainability transitions in healthcare systems.

8.4 RECOMMENDATIONS FOR FUTURE RESEARCH

The following recommendations are identified as viable options for future work which elaborates on this research:

i. Expand the research to the application of the framework in other societal systems and present case studies on the implementation of lean thinking to support sustainability transitions;
ii. Expand the LT4STHC framework, methodology, and LT4ST index to include other sustainability transition aspects which possibly occur during a transition and could require support;
iii. Expand the research to examine the possible negative effect that lean thinking could have and its effect on sustainability transitions, i.e., socio-technical transitions;

iv. Explore more lean thinking approaches and principles that could be considered to support aspects of sustainability transitions in healthcare;

v. Expand the framework, methodology, and index to ensure that it is applicable in both the private and public healthcare sectors;

vi. Expand the LT4STHC framework to include other system demarcations, such as value streams and supply chain interactions; and

vii. Expand the LT4STHC framework's operationalisation strategy to provide the user with an outlet for exercising strategic intent from the understanding developed by utilising the framework in analysis. STTs theory presents analytical frameworks such as MLP, TIS, SNM and TM (presented in Section 5.2) that help shape an approach towards identifying, understanding, and strategising efforts to influence transitions.

8.5 CHAPTER 8: CONCLUSION

This chapter provided a summary of the research involved in this study. It also discussed how the research objectives were reached and how they sequentially progressed toward achieving the aim of this research study. The recommendations for future research about this study concluded the chapter.

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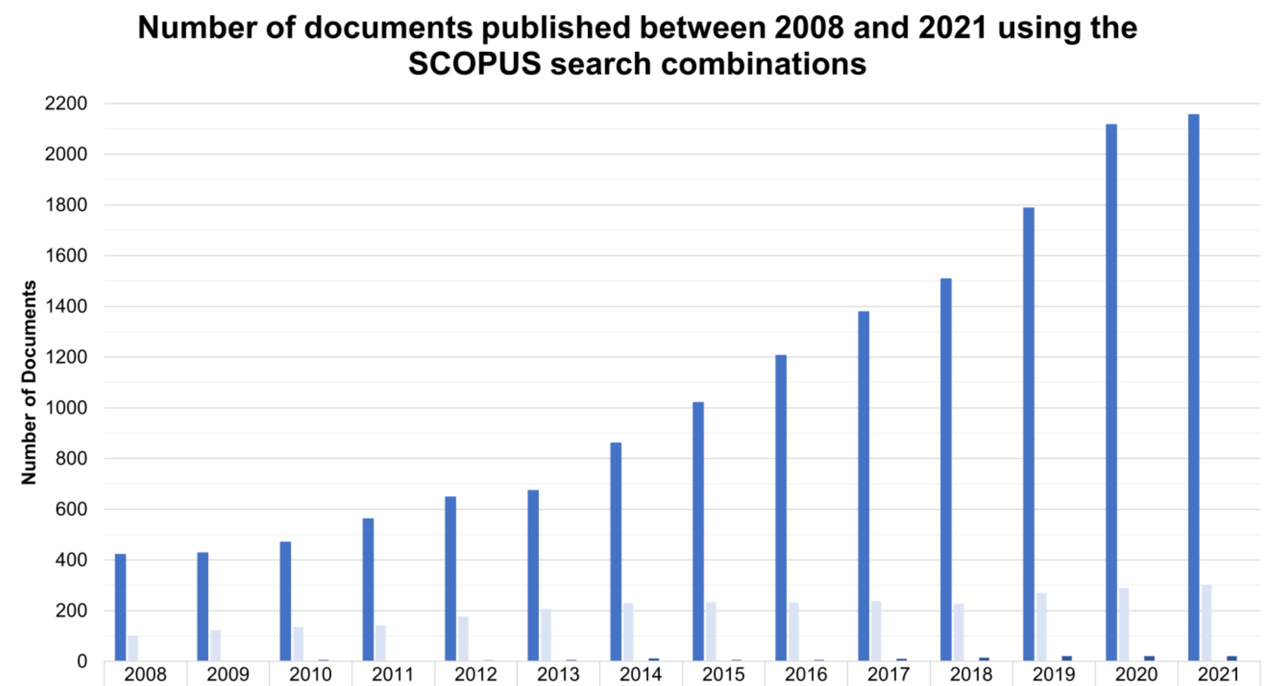
APPENDIX A: SUPPORTING CONTENT FOR CHAPTER 1

Table 47: SCOPUS search combinations & results

Key terms	1	2	3		4	5		6	7
Healthcare or health care	x	x	x		x	x		x	x
Sustainability or sustainable development	x				x	x		x	
Sustainable transition(s) or sustainability transition(s)			x			x		x	x
Lean or lean principle(s)		x			x			x	x
Number of published documents	**17 723**	**3 300**	**15**		**133**	**11**		**0**	**0**
Number of published documents in South Africa	**713**	**0**	**0**		**0**	**0**		**0**	**0**

Table 48: Number of documents obtained using search combinations

Search Combination Label	Scopus Algorithm	Number of documents obtained
SC1.1	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("sustainability" OR "sustainable development"))	17 723
SC1.2	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("lean" OR "lean principle*"))	3 300
SC1.3	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("sustainable transition*" OR "sustainability transition*"))	15
SC1.4	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("sustainability" OR "sustainable development") AND TITLE-ABS-KEY ("lean" OR "lean principle*"))	133
SC1.5	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("sustainability" OR "sustainable development") AND TITLE-ABS-KEY ("sustainable transition*" OR "sustainability transition*"))	11
SC1.6	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("sustainability" OR "sustainable development") AND TITLE-ABS-KEY ("sustainable transition*" OR "sustainability transition*") AND TITLE-ABS-KEY ("lean" OR " lean principle*"))	0
SC1.7	(TITLE-ABS-KEY ("healthcare" OR "health care") AND TITLE-ABS-KEY ("sustainable transition*" OR "sustainability transition*") AND TITLE-ABS-KEY ("lean" OR "lean principle*"))	0



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
SC1	422	428	470	561	648	673	860	1021	1206	1378	1508	1788	2117	2156
SC2	100	123	135	142	178	207	231	233	232	238	227	269	289	302
SC3	0	0	0	1	0	0	3	0	2	1	2	0	3	3
SC4	3	3	6	2	4	5	11	6	6	10	15	20	21	21
SC5	0	0	0	1	0	0	2	0	2	0	2	0	3	1

Figure 47: Number of published documents in SCOPUS based on SCs

APPENDIX B: SUPPORTING CONTENT FOR CHAPTER 6

Table 49: Lean4Tension

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
1. Lean4Tension	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓	✓	✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow							✓	
	Pull System		✓	✓	✓			✓	
	Heijunka								
	Jidoka			✓	✓	✓		✓	✓
	Standardise Tasks	✓	✓	✓	✓				
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓				
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓			✓	
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods								
	Transition Management				Analytical Perspectives				
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	
	Controlling the entire process	✓	✓	✓	✓			✓	
	Improving the process continuously	✓	✓	✓	✓			✓	
	Gathering information about competitors	✓	✓	✓	✓			✓	
	Reduction of raw materials	✓	✓	✓	✓			✓	
	Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 50: Lean4Stress

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
2. Lean4Stress	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System		✓	✓	✓			✓	
	Heijunka		✓	✓	✓			✓	
	Jidoka			✓	✓	✓		✓	✓
	Standardise Tasks	✓	✓	✓	✓	✓		✓	
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 51: Lean4Pressure

Lean4…		Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
3. Lean4Pressure	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓	✓	✓	✓	✓	✓	✓
	Grow lean leaders								
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System		✓	✓	✓			✓	
	Heijunka								
	Jidoka			✓	✓	✓		✓	✓
	Standardise Tasks								
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	
	Controlling the entire process	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 52: Lean4Progress

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
4. Lean4Progress	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu								
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System		✓	✓	✓			✓	
	Heijunka		✓	✓	✓			✓	
	Jidoka								
	Standardise Tasks	✓	✓	✓	✓	✓		✓	
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	
	Controlling the entire process	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 53: Lean4Stability

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
5. Lean4Stability	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System		✓	✓	✓			✓	
	Heijunka		✓	✓	✓			✓	
	Jidoka			✓	✓	✓		✓	✓
	Standardise Tasks	✓	✓	✓	✓	✓		✓	
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	
	Controlling the entire process	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 54: Lean4Adaptability

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
6. Lean4Adaptability	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu								
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow								
	Pull System		✓	✓	✓			✓	
	Heijunka								
	Jidoka								
	Standardise Tasks								
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	
	Controlling the entire process	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 55: Lean4Failures

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
7. Lean4Failures								
Lock-Ins								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders								
Lean for the people (team & suppliers)								
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks	✓	✓	✓	✓	✓		✓	
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude								
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value								
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time								
Simplifying the process								
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors								
Reduction of raw materials								
Efficient allocation of human resources								
System Breakdown								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)								
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks								
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time								
Simplifying the process	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials								
Efficient allocation of human resources	✓	✓	✓	✓			✓	
Backlash								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)			✓					
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks	✓	✓	✓	✓	✓		✓	✓
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value								
Reducing uncertainty	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time								
Simplifying the process								
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials								
Efficient allocation of human resources	✓	✓	✓	✓			✓	
Directionality Failure								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks	✓	✓	✓	✓	✓		✓	
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude								
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Lean Principles								
Reducing/Eliminating activities that do not add value								
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time								
Simplifying the process								
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors								
Reduction of raw materials								
Efficient allocation of human resources								
Demand Articulation Failure								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks	✓	✓	✓	✓	✓		✓	✓
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value								
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time								
Simplifying the process	✓	✓	✓	✓			✓	
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials								
Efficient allocation of human resources	✓	✓	✓	✓			✓	
Policy Coordination Failure								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)			✓					
Create process flow								
Pull System		✓	✓	✓			✓	
Heijunka							✓	
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks	✓	✓	✓	✓	✓		✓	
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements								
Reduce cycle time								
Simplifying the process								
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials								
Efficient allocation of human resources								
Reflexivity Failure								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								

Lean4…	**Analytical Methods**							
	Transition Management				**Analytical Perspectives**			
	TMS	**TMT**	**TMO**	**TMR**	**APDS**	**APPD**	**APPS**	**APDN**
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks	✓	✓	✓	✓	✓		✓	
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements								
Reduce cycle time								
Simplifying the process	✓	✓	✓	✓			✓	
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials								
Efficient allocation of human resources								

Table 56: Lean4Weaknesses

Lean4…		Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
8. Lean4Weaknesses	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System		✓	✓	✓			✓	
	Heijunka		✓	✓	✓			✓	
	Jidoka								
	Standardise Tasks	✓	✓	✓	✓	✓		✓	
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time								
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

Table 57: Lean4SNM

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
9. Lean4SNM	**4P Model of the Toyota Way & Liker's Lean**								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System		✓	✓	✓			✓	
	Heijunka		✓	✓	✓			✓	
	Jidoka			✓	✓	✓		✓	✓
	Standardise Tasks	✓	✓	✓	✓	✓		✓	
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time								
	Simplifying the process								
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials								
Efficient allocation of human resources								

Table 58: Lean4Pathways

	Lean4…	Analytical Methods							
		Transition Management				Analytical Perspectives			
		TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
10. Lean4Pathways	**Transformation Pathway**								
	4P Model of the Toyota Way & Liker's Lean								
	Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
	Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
	Slow decision-making	✓	✓		✓	✓	✓	✓	✓
	Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
	Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
	Create process flow		✓	✓	✓			✓	
	Pull System								
	Heijunka		✓	✓	✓			✓	
	Jidoka			✓	✓	✓		✓	✓
	Standardise Tasks								
	Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
	Lean Practices & Approaches								
	Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
	Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
	Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
	Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
	Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
	Lean Principles								
	Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
	Reducing uncertainty	✓	✓	✓	✓			✓	
	Focus on customer requirements	✓	✓	✓	✓			✓	
	Reduce cycle time	✓	✓	✓	✓			✓	
	Simplifying the process	✓	✓	✓	✓			✓	
	Increase production flexibility	✓	✓	✓	✓			✓	
	Increase process transparency	✓	✓	✓	✓			✓	

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	
De-alignment and re-alignment pathway								
<u>4P Model of the Toyota Way & Liker's Lean</u>								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu								
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders								
Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
Create process flow								
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks								
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
<u>Lean Practices & Approaches</u>								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
<u>Lean Principles</u>								
Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	

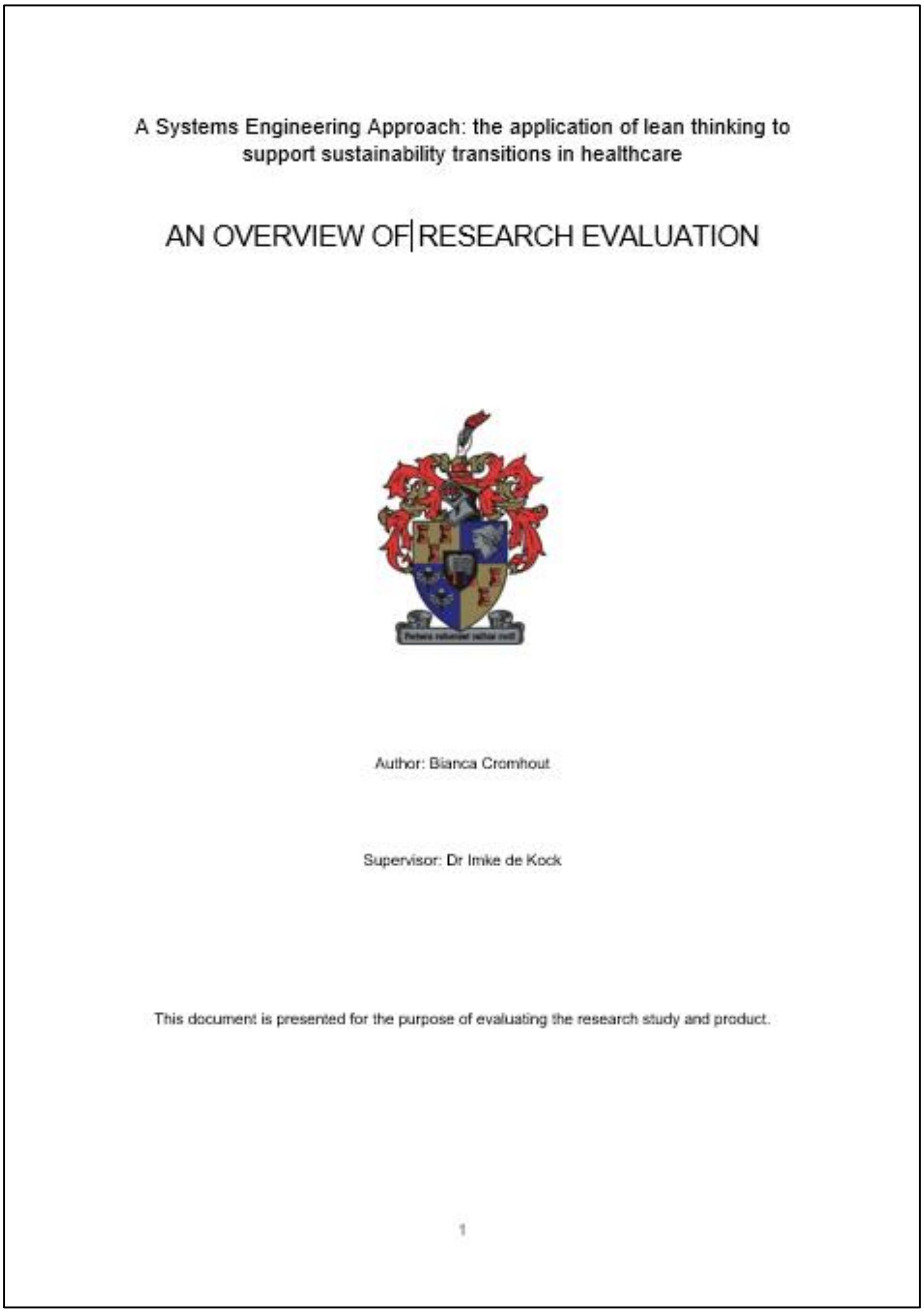
Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Reduce cycle time	✓	✓	✓	✓			✓	
Simplifying the process	✓	✓	✓	✓			✓	
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	
Technological substitution								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu	✓	✓	✓	✓	✓	✓	✓	✓
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders	✓	✓	✓	✓	✓	✓	✓	✓
Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka		✓	✓	✓			✓	
Jidoka								
Standardise Tasks	✓	✓	✓	✓	✓		✓	
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Lean Principles								
Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time	✓	✓	✓	✓			✓	
Simplifying the process	✓	✓	✓	✓			✓	
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	
Reconfiguration pathway								
4P Model of the Toyota Way & Liker's Lean								
Kaizen	✓	✓	✓	✓	✓	✓	✓	✓
Genchi Genbutsu								
Slow decision-making	✓	✓		✓	✓	✓	✓	✓
Grow lean leaders								
Lean for the people (team & suppliers)	✓	✓	✓	✓			✓	
Create process flow		✓	✓	✓			✓	
Pull System		✓	✓	✓			✓	
Heijunka								
Jidoka			✓	✓	✓		✓	✓
Standardise Tasks								
Long-term philosophy (Lean Journey)	✓	✓	✓	✓	✓		✓	
Lean Practices & Approaches								
Mindset & Attitude	✓	✓	✓	✓	✓	✓	✓	✓

Lean4…	Analytical Methods							
	Transition Management				Analytical Perspectives			
	TMS	TMT	TMO	TMR	APDS	APPD	APPS	APDN
Leadership & Management	✓	✓	✓	✓	✓	✓	✓	✓
Employee Involvement	✓	✓	✓	✓	✓	✓	✓	✓
Tools & Techniques	✓	✓	✓	✓	✓	✓	✓	✓
Six Sigma	✓	✓	✓	✓	✓	✓	✓	✓
Lean Principles								
Reducing/Eliminating activities that do not add value	✓	✓	✓	✓			✓	
Reducing uncertainty	✓	✓	✓	✓			✓	
Focus on customer requirements	✓	✓	✓	✓			✓	
Reduce cycle time	✓	✓	✓	✓			✓	
Simplifying the process	✓	✓	✓	✓			✓	
Increase production flexibility	✓	✓	✓	✓			✓	
Increase process transparency	✓	✓	✓	✓			✓	
Controlling the entire process	✓	✓	✓	✓			✓	
Improving the process continuously	✓	✓	✓	✓			✓	
Gathering information about competitors	✓	✓	✓	✓			✓	
Reduction of raw materials	✓	✓	✓	✓			✓	
Efficient allocation of human resources	✓	✓	✓	✓			✓	

APPENDIX C: SUPPORTING CONTENT FOR CHAPTER 7

Figure 48: Overview document provided to SMEs



A Systems Engineering Approach: the application of lean thinking to support sustainability transitions in healthcare

AN OVERVIEW OF RESEARCH EVALUATION

Author: Bianca Cromhout

Supervisor: Dr Imke de Kock

This document is presented for the purpose of evaluating the research study and product.

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1 PROJECT BACKGROUND AND PROBLEM STATEMENT

Sustainability is not only a fairly new concept, but it has become more popular as time passed due to the increase in the need to understand and acknowledge resource scarcity. This concept has originated from movements such as social justice, conservationism, internationalism, etc. which by the end of the 20th century came together as a collective to be called 'sustainable development'. In 1987 the Brundtland Commission released a famous definition for the term 'sustainable development', which is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (University of Alberts, 2016). Sustainability is deemed a holistic approach in which economic, social, and environmental aspects must all be considered together to find a lasting existence of prosperity (University of Alberts, 2016).

The development of sustainable healthcare systems has increasingly become a more difficult task to achieve, due to the intense amount of competition in the healthcare industry. Sustainable healthcare systems are the gateway to providing higher quality healthcare at lower costs while reaching large populations in a certain area and effectively managing diseases. Cost efficiency and the effectiveness of a healthcare system cannot be achieved simultaneously. Researchers have also proven that there is an evident compromise between the increases that occurs between effectiveness and efficiency. The effectiveness is an indication of the potential of the healthcare system to be able to achieve its maximum possible output (lo Storto & Goncharuk, 2017).

In this reseach project a systems engineering approach (SEA) is followed, as illustrated by Figure 1, which allows for an extensive selection of possible approaches that transform the customer's operational needs into solutions. SEA is furthermore selected because it transforms needs into suitable solutions to solve a problem while considering sustainable methods (United States Government, 2001).

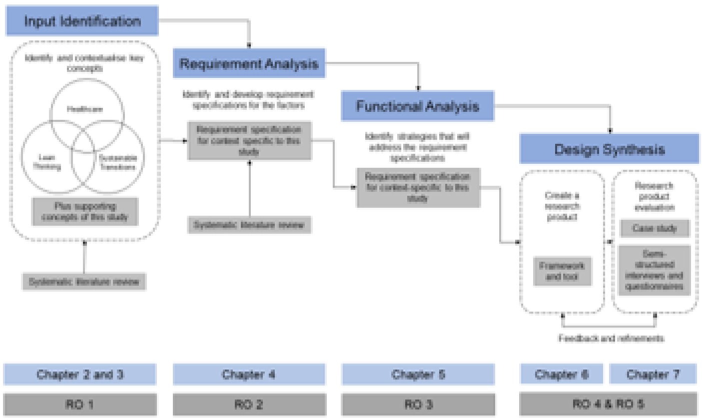

Figure 1: Adapted Systems Engineering Approach (Huysamen, 2020)

Literature has demonstrated that there is a global need to meet the sustainable development goals (SDGs)(United Nations, 2022). Various analyses have been conducted on sociotechnical transitions to understand how societal systems, including healthcare systems, can be configured to achieve increased sustainability and to reach sustainability goals. Sociotechnical transitions have become a demanding topic of global sustainability debates (Kohler, et al., 2019). Given this global sustainability

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problem, methods and approaches to support the transition towards sustainability are required to ease the transition process (European Commission, 2020).

The problem which this research aims to address can be looked at from two perspectives. The practical perspective considers the fact that there are multiple challenges in the healthcare industry, including unsustainability, which can be solved using multiple solutions. Preliminary research indicates that there is a need to identify and understand how sustainability transitions in healthcare can be facilitated or supported by lean thinking. Research has proven that lean thinking and sustainability match in terms of objectives and achieving the main goal of processes (Khodier & Othman, 2018).

From a theoretical perspective, it is clear that there is a knowledge gap in the combined focus areas of this research, i.e., healthcare, sustainable transitions, sustainability transitions, and lean or lean thinking.

2 INTRODUCTION

This section provides an overview of the introduction to the study which is found in Chapter 1 of the thesis document. The purpose of this overview is to familiarise the reader with the concepts of lean thinking to support sustainability transitions in healthcare. The most important aspect is the presentation of the research problem, aim and objectives.

2.1 SUSTAINABILITY TRANSITION APPROACHES IN HEALTHCARE

Researchers and practitioners have directed much attention towards the increase in environmental concerns and highlights the need for multiple actors in a system to increase the rate of sustainability transitions (Geels, 2019; Lynch, Klaassen, Van Wassenaer, & Broerse, 2020). The research on transitions has expanded much over the past three decades (Markard, Raven, & Truffer, 2012; Kohler, Geels, Kern, & al, 2019). It has evolved from shaping technology and social changes into a multi-disciplinary social science field that has been dealing with the increasing importance of social and environmental sustainability (EEA, 2019). The initial focus of sustainable transitions was in the electrical and transportation sectors but has now expanded to other domains including healthcare (van den Bergh, et al., 2021). Given that environmental and social challenges are recurring events, it is likely that research about transitions will remain relevant and become increasingly important (Markard, et al., 2020).

Transitions can occur through regime change or transformation. Regime changes are evident when the current regime is unable to adapt to the pressures of the landscapes and niches. The regime is then replaced by another which is capable of dealing with the landscape and niche pressures. Regime transformations are evident when the current regime responds to those pressures and changes some of the regulations within the regime to enable it to accommodate the new changes (Bergman, et al., 2008). The healthcare industry has long been a clear indication of well-being within the direct modern community. This resource faces the challenge of not yet being able to adequately address critical problems without fundamental changes occurring (Broerse & Grin, 2017). However, the available literature resources on sustainable transitions in healthcare all had the common goal of achieving a global culture and active engagement in continuous quality improvement (Roy, et al., 2016; Broerse & Grin, 2017; Berg, 2011). The implementation of lean within healthcare institutes, globally, all have a common challenge in achieving higher levels of sustainability. Research indicates that "experimentation is an important capability in the transition to a sustainable business". These experiments aim to improve the current level of innovative activities in business models despite the limited resources available. The circular economy[1] is the main driver of sustainability (Bocken, et al., 2018).

1. Circular Economy is defined as 'a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended' (European Parliament, 2015)

7 approaches to understand sustainability transitions have been selected for this study, being:

(i) Forces for transitional change in synthesis with multi-level perspective (MLP) (to understand and identify how lean thinking could contribute to supporting *landscape tensions*, *regime stress*, and *niche pressure*); and

Table 1: Forces driving transitional change (De Kock, 2020; Frantzeskaki & de Haan, 2009)

Forces driving transitional change			Conditions for transitional change
Tension	↓	Top-down force	A mismatch between the functions of the regime and landscape
Stress	♻	Internal	Internal mismatch of the function of the regime
Pressure	↑	Bottom-up force	Pressure of a competitive alternative to the regime function

	Direction of change			Clustering of forces influencing transitions		
Forces driving transitional change	↓	♻	↑	Formation Forces	Support Forces	Trigger Forces
Crises, exogenous events	x					x
Standardisation of practices/routines	x				x	
Provision of resources	x				x	
Exercise of power (over the system by external or internal centres of influence)	x				x	
Imposition of a new functioning	x					
Systemic failures		x				x
Self-regulation of the system		x			x	
Presence of a niche			x	x		
Presence of a new demand			x	x		
Presence of a new functioning	x		x	x		

(ii) Transitional and transformational failures (to understand and identify how lean thinking can support the occurrence of different *transition failures*); and

Table 2: Transition failures (Van der Brugge & Rotmans, 2007)

Transition Failure	Description
Lock-in	"A transition path where an innovation does gain influence in the societal system, but fails to completely replace the regime co-existing with it in a locked-in state. Lock-ins occur when the unsustainable (incumbent) regime remains to co-exist alongside competing innovations, or when competing innovations co-exist but none of these innovation networks are powerful enough to stabilise as the new regime, thus creating a lock-in of innovations".
System breakdown	"A system breakdown refers to the event where there are no innovation networks available that become self-sufficient, and all innovation networks continue to compete for the same resources; this results in no viable alternative being available. Alongside this, a regime is destabilising, meaning that it can no longer fulfil the societal functions. However, because no alternative is available, the system breaks down."
Backlash	"When niches that initially gained power and popularity, and thus progressed to the 'take-off' phase, subsequently fail to become the mainstream practice to

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	meet societal needs, the system experiences backlash. This can happen if, for example, the demand for a certain functioning increases quickly, but the niche is unable to cope with such drastic increases in demand and/or changes in demand, and thus fails. In another scenario, some novel functioning could be initially adopted by many, until unexpected challenges arise and the niche is no longer adopted by users as a mainstream practice; in this case, too, backlash can occur."

Table 3: Transformational Failures (Walrave & Raven, 2016; Weber & Rohracher, 2012)

Description	Examples of overcoming these failures	Examples of key mechanisms that lead to the occurrence of the failure
Directionality failure		
Directionality failure pertains to the observation that a need to consider the direction of innovation in such a way that the innovation contributes towards societal challenges, exists. These failures are also associated with the occurrence that one is locked-in a particular solution that is not optimal from a long-term perspective.	To overcome directionality failure it is required that the guiding orientations are translated and that the intermediation of guiding orientations occur (external requirements to the innovation system need to be absorbed, and need to be interpreted and negotiated in order to provide direction for the different relevant actors).	- lack of shared vision regarding the goal and direction of the transformation process; and - incapability of collective coordination of actors that are involved in the shaping of systemic change; and - a lack of sufficient regulations and standards to provide guidance for the direction of the systemic change; and - insufficient targeted funding for research and development, projects, and infrastructure that can facilitate the development of acceptable development paths.
Demand Articulation Failure		
Demand articulation failures pertains to the observation that markets for new innovations (technologies specifically) may not (yet) exist, and could result in a lack of articulation of what these markets require, or what user preferences are (results in a lack of being able to anticipate user needs).	Support learning processes that involve producers and users (e.g. strategic niche management); and more attention is paid to new and neglected forms of innovation; and integrating consumers and producers in innovation processes; and creating and increasing awareness of new possibilities; and innovation-oriented procurement mechanisms; and policy support to facilitate building up the competencies of potential users to articulate their needs and demands.	- insufficient opportunities for anticipating and learning about user needs; and - the lack of orientation and stimulating signals from public demand; and - a lack of demand-articulating competencies
Policy Coordination Failure		
Policy coordination failures refers to the observation that policies and institutional standards may need to transform to respond to the challenges and to adequately support the development of	It is important to ensure that there is coherence between the activities which exist on national, regional, sectoral and technological institutional levels. The harmonisation of research and development funding and	- the lack of cross-level policy coordination; and - a lack of horizontal coordination between research, technology, and innovation policies , and on the other hand sectoral policies; and

innovations to address these challenges.	the regulatory environment is important.	- a lack of temporal coordination that could result in misalignment between the timing of interventions and system actors.
Reflexivity Failure		
Reflexivity failures refer to the observation that there is a need to monitor the development of technology innovations on a continuous basis, with regards to such systems' contributing to the broader development of adaptation strategies.	The provision of platforms for interactions and opportunities for experimentation, monitoring and learning among different actors and platforms; and learning through the actors by reflecting on the conditions for change and to engage in the transformation of the systems in which they operate.	- a lack of monitoring, anticipating, and inclusion of actors in processes of self-governance; and - a lack of distributed reflexive arrangements to connect different sectors in order to provide opportunities for experiments and learning; and - a lack of adaptive policies that allows for policy options to be kept open in order to deal with uncertainty

(iii) Innovation System Approach (to understand and identify how lean thinking can support *system weaknesses* in the study of sustainability transitions); and

(iv) Strategic Niche Management (to understand and identify how lean thinking can support the *introduction and diffusion of new sustainable technologies* through societal experiments); and

(v) Transition Management (to understand and identify whether the lean thinking can be used at a *strategic, tactical, operational* or *reflexive level*); and

(vi) The Resilience of a Sustainability Transition (RST) (to understand and identify how lean thinking can be used to support *progress, stability*, and *adaptability*; and

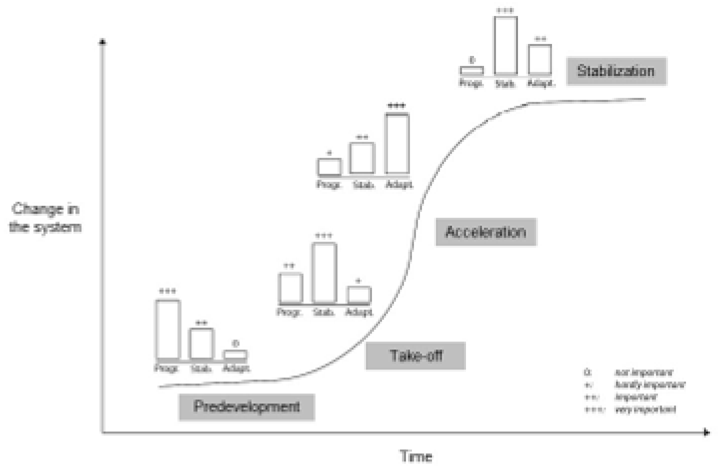

Figure 2: Importance of RST dimensions across transition phases (Schilling, et al., 2018).

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(vii) Transition Pathways (to understand and identify how lean thinking can support different *transition pathways*).

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Table 4: Transition Approach Nr. 7 – Transition pathways

	P0	P1			P2	P3		P4
	Reproduction Pathway	**Transformation Pathway**			**De-alignment and re-alignment**	**Technological substitution**		**Reconfiguration Pathway**
		Gradual reorientation of the existing regime through adjustments by incumbent actors in the context of landscape pressures, societal debates, and tightening institutions			Existing regime is disrupted by external shocks, which in followed by the rise of multiple niche innovations and constituencies, ones of which gradually becomes dominant.			Niche-innovations and the existing regime combine to transform the system's architecture
Landscape pressure	x	✓			✓	✓		✓
Niche innovation sufficiently developed		x			x	✓		✓
Actors		Incumbents reorient incrementally by adjusting search routines and procedures		Incumbents reorient substantially to radical, new technology, or even more deeply to new beliefs, missions and business models	Incumbents collapse because of landscape pressure, creating opportunities for new entrants	New firms struggle against incumbent firms, leading to overthrow	Different kinds of new contestants (e.g., citizens, communities, social movement actors, incumbents from different sectors) replace incumbents	New alliances between incumbents and new entrants
Technologies		Incremental improvements in existing technologies (leading to major performance enhancement over long time periods)	Incorporation of symbiotic niche innovations and add-ons (competence adding, creative accumulation)	Reorientation towards new technologies: (a) partial reorientation (diversification) with incumbents developing both old and new technologies; (b) full reorientation, leading to technological substitution	The decline of old technologies creates space for several innovations which compete with one another.	Radical innovation(s) substituting existing technologies		From additional add-ons to new combinations between new and existing technologies; knock-on effects and innovation cascades that change system architecture
Operational changes required		Demonstration of viable alternatives may change perceptions of regime insiders and lead to reorientations of innovative activities			Multiple niche-innovations co-exist and compete for attention and resources	Incremental innovations, technology-push character		Substantial changes in the regime's basic architecture, multiple component-innovations
Rules and institutions		Limited institutional change (layering)		Substantial change in institutions (conversion, displacement)	Institutions are disrupted by shocks and replaced, possibly after prolonged uncertainty (Disruption)	Limited institutional changes, implying that niche innovation needs to compete in the existing selection environment also referred to as "fit-and-conform" (incremental adjustment, layering)	Creation of new rules and institutions to niche innovations also referred to as "stretch-and-transform" (disruption, displacement	From limited institutional change (layering) to more substantial change, including operational principles ('drift', 'conversion')

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2.2 LEAN THINKING

Lean is a very popular methodology in the manufacturing industry, but it is not frequently used in healthcare (D'Andreamatteo, et al., 2015). A lean methodology is an approach to systematically eliminating waste within a process or production system (Dondofema, et al., 2017). Liker's lean (2004) describes 14 principles that are based on 20 years of studying and examining Toyota, one of the top-performing car manufacturing companies. As illustrated in Figure 3, these principles are the baseline for the Toyota Production System (TPS), a combination of socio-technical systems consisting of management practices and philosophies (Ohno, 1988).

The following lean thinking approaches and principles have been selected to form part of the final considerations for implementing lean thinking to support sustainability transitions in healthcare.

<u>4P Model of the Toyota way & Liker's Lean Model</u>

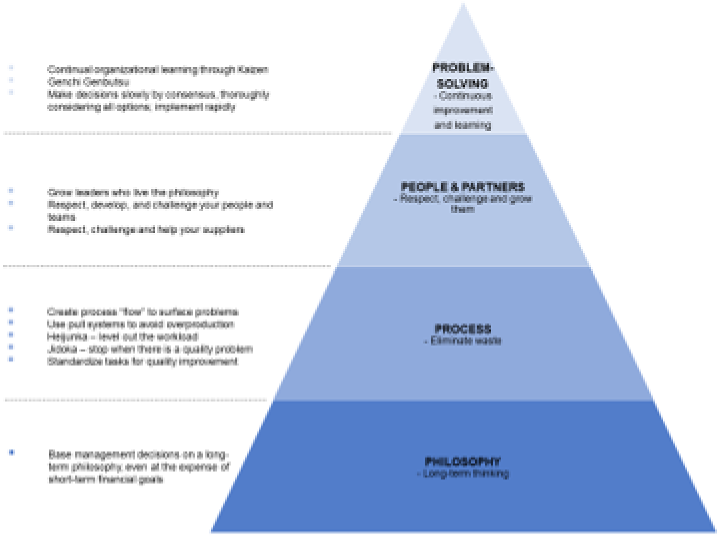

Figure 3: 4P Model of the Toyota Way & Liker's Lean

<u>Lean Practices and Approaches</u>

The industrial globalisation of the healthcare industry has provided increased opportunities for cost-effectiveness and the promotion of quality in the development and growth of this sector. However, it also leads to increased responsibilities regarding regulations and boundaries which results in zero waste (Khan, et al., 2020). The healthcare industry has access to a limited number of resources, and the healthcare industry should simultaneously take economic, social, and environmental issues into account by adopting lean and green principles which enhance competitiveness in a sustainable manner (Siegel, et al., 2019).

MINDSET AND ATTITUDE - This fundamental aspect of the lean methodology consists of implementing methods and practices which have a long-term commitment toward lean green practices. The majority of lean principle implementations fail due to the lack of understanding and communication; therefore, it is important to ensure that the cognitive dimension, applicable tools, and concepts are learned. Researchers have determined that mindset and attitude is the key concept which determines the success of lean implementation (Zhan, et al., 2018).

LEADERSHIP AND MANAGEMENT - To ensure a continual long-term lean investment in the employees as well as maintain their willingness towards the promotion of lean culture, the leadership in the organisation should commit as well. Leaders should have an in-depth understanding of the lean journey, as to ensure that a lean culture is manifested and to ensure that people with the required set of skills are in the right positions to ensure a successful lean journey (Zhan, et al., 2018).

EMPLOYEE INVOLVEMENT - According to Zhu et al. (2005), the success of lean implementation is determined by the level of effort from the employees in the organisation, which in turn will improve the environmental and business performance of the organisation. As a long-term approach, it requires permanent and devoted commitment which starts with the willingness to change. The core of the lean principle implementation is the development of human capital. The overall lean journey should be linked with employee development (Womack & Jones, 2003). Employees should also be actively involved during the entire lean journey, especially during the initial planning and final execution phase (Zhan, et al., 2018).

TOOLS AND TECHNIQUES - The implementation of lean tools and techniques has proven to be competitive as well as improve the state of the business' level of performance. Quality and customer satisfaction are two of the strongest drivers of lean implementation and they must receive preference. Lean tools and techniques improve performance without decreasing the ecologically based efficiency while contributing to increased sustainability (Thanki, et al., 2016). These tools and techniques are identified as lean thinking which "aim to identify and remove waste with optimisation of resource utilisation". The most common and influential lean tool is the 5S (sort, set, shine, standardise, sustain) tool, with an added sixth category which pertains to safety. This tool in combination with value stream mapping is the most commonly applied lean tool (Chiarini, 2014; Piercy & Rich, 2015). The United States Environmental Protection Agency (2007) has developed and introduced a 'toolkit' to provide environmental practitioners and lean operations managers with practical techniques which reduce business risk and cost and identify and eliminate waste (Zhan, et al., 2018).

Other tools and techniques, including those mentioned above, are: Bottleneck Analysis, Overall Equipment Effectiveness, Plan-Do-Check-Act, Error Proofing, Root Cause Analysis, SQDC (Safety, Quality, Delivery, Cost), A3 Lean Thinking Process, Waste Observation Chart, Process Flow Map, Change management plan, Poka Yoke (mistake proofing), Hoshin Kanry (defines the company objectives under Lean principle). Kanban (a mechanism to flow control and production control, allowing the production of only what is needed in the moment when it is needed and in the quantity needed), Andon (visual signal to inform when something is wrong or is in an abnormal condition), SMED (created by Shingo, reduce the setup times, complete as many steps as possible while the equipment is running or processing, so as to save time and quickly change-over to processing the next product), etc.

SIX SIGMA - Six Sigma is a management approach which has grown as an addition to total quality management (TQM). The application of this approach, which has been implemented in healthcare systems, reduces the occurrence of defects in products and services. Six sigma can also be defined as "a statistical set contained with quality management for the construction of a framework for process improvement" (Khan, et al., 2020). It can also be defined as "a customer-oriented, systematic, structured, multifaceted, proactive, business improvement quantitative philosophical approach to speed up deliveries, reduce cost and to increase quality" (Khan, et al., 2020).

Lean Principles and Sustainability Principles

Sustainability's Principle	Lean's Principle												Similarities	Complementarity	SDG
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12			
S1	x	x		x			x		x		x	X	Reducing resources	Lean responds punctually to different resources	SDG 9 SDG 12
S2		x	x				x						Time efficiency	Lean streamlines operations; sustainability plans	SDG 9 SDG 12
S3			x		x								Waiting time	Lean gets the product in a short time; sustainability reduces the time allotted	SDG 9 SDG 12
S4									x		x		Process costs	Lean gets the product in a short time; sustainability reduces the time allotted	SDG 12 SDG 17
S5										x		x	Stakeholder interest	Lean evaluates competitors' operations and allocates efficient human resources; sustainability involves stakeholders in decision-making	SDG 6 SDG 8 SDG 17
S6			x									x	Activities for people	Lean involves employees; sustainability supports the organization's involvement in society	SDG 2 SDG 3 SDG 16
S7								x				x	Human resources	Lean pursues resource efficiency; sustainability supports employee training	SDG 4 SDG 5
S8												x	CSR	Lean sustains organizational efficiency; sustainability activities for society	SDG 1 SDG 10
S9					x	x			x				Recycling	Lean aims to reduce losses; sustainability aims to increase the recycling rate	SDG 14 SDG 15
S10	x					x		x					Reverse logistics	Lean supports loss reduction; sustainability supports reverse logistics (returning waste to production as raw materials)	SDG 7 SDG 12
S11		x			x	x	x	x	x				Energetic efficiency	Lean reduces loss; sustainability sustains the production of green energy	SDG 9 SDG 13
S12	x			x	x			x	x		x		Pollution Reduction	Lean reduces waste; sustainability is aimed at reducing greenhouse gases	SDG 11 SDG 13

Figure 4: Lean Principles & Sustainability Principles

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2.3 LEAN & SUSTAINABILITY TRANSITION IN HEALTHCARE SYNTHESIS

The final synthesis, as illustrated by Figure 5, is the implementation of lean thinking into sustainability transition approaches. This step was conducted by analysing the previous sections, approaches for transitional change in healthcare, to determine which identified lean thinking approach or principle, as mentioned in Section 2.2, could support the

i. Forces and Conditions for Transitional Change (landscape tensions, regime stresses, and niche pressures in healthcare),
ii. Transitional and Transformational failures (Lock-ins, System breakdown, Backlash, Directionality failure, demand articulation failure, policy coordination failures, reflexivity failures),
iii. Innovation System Approach (TIS),
iv. Strategic Niche Management (SNM),
v. RST (progress, stability and adaptability in healthcare), and
vi. Transition pathways (transformation pathway, de-alignment and re-alignment pathway, technological substitution, reconfiguration pathway in healthcare).

Transition Management, as identified and discussed, will be used to determine at what level the lean thinking approaches or principles could support the 6 other approaches:

i. strategic level (**TMS**); and
ii. tactical level (**TMT**); and
iii. operational level (**TMO**), and
iv. reflexive level (**TMR**).

Four different analytical perspectives were also considered to conduct the final synthesis phase, being the:

i. descriptive analytical perspective (**APDS**), which pertains to understanding what has happened,
ii. predictive analytical perspective (**APPD**), which pertains to understanding what could happen in the future based on previous trends or patterns,
iii. prescriptive analytical perspective (**APPS**), which pertains to understanding what the business should do moving forwards, and
iv. diagnostic analytical perspective (**APDN**), which pertains to understanding why what happened happened. Each lean thinking approach or principle was classified and assigned according to these two analytical approaches.

Illustrated (in red writing) in Figure 5, certain aspects were identified that contribute towards the construction of the conceptual framework of this study. These are:

1. Lean4Tension (lean thinking approaches and principles that could aid in supporting landscape tensions); and
2. Lean4Stress (lean thinking approaches and principles that could aid in supporting regime stress); and
3. Lean4Pressure (lean thinking approaches and principles that could aid in supporting niche pressure); and
4. Lean4Progress (lean thinking approaches and principles that could aid in supporting progress); and
5. Lean4Stability (lean thinking approaches and principles that could aid in supporting stability); and
6. Lean4Adaptability (lean thinking approaches and principles that could aid in supporting adaptability); and
7. Lean4Failures (lean thinking approaches and principles that could aid in supporting failures); and

8. Lean4Weaknesses (lean thinking approaches and principles that could aid in supporting weaknesses); and
9. Lean4SNM (lean thinking approaches and principles that could aid in supporting strategic niche management); and
10. Lean4Pathways (lean thinking approaches and principles that could aid in supporting different transition pathways).

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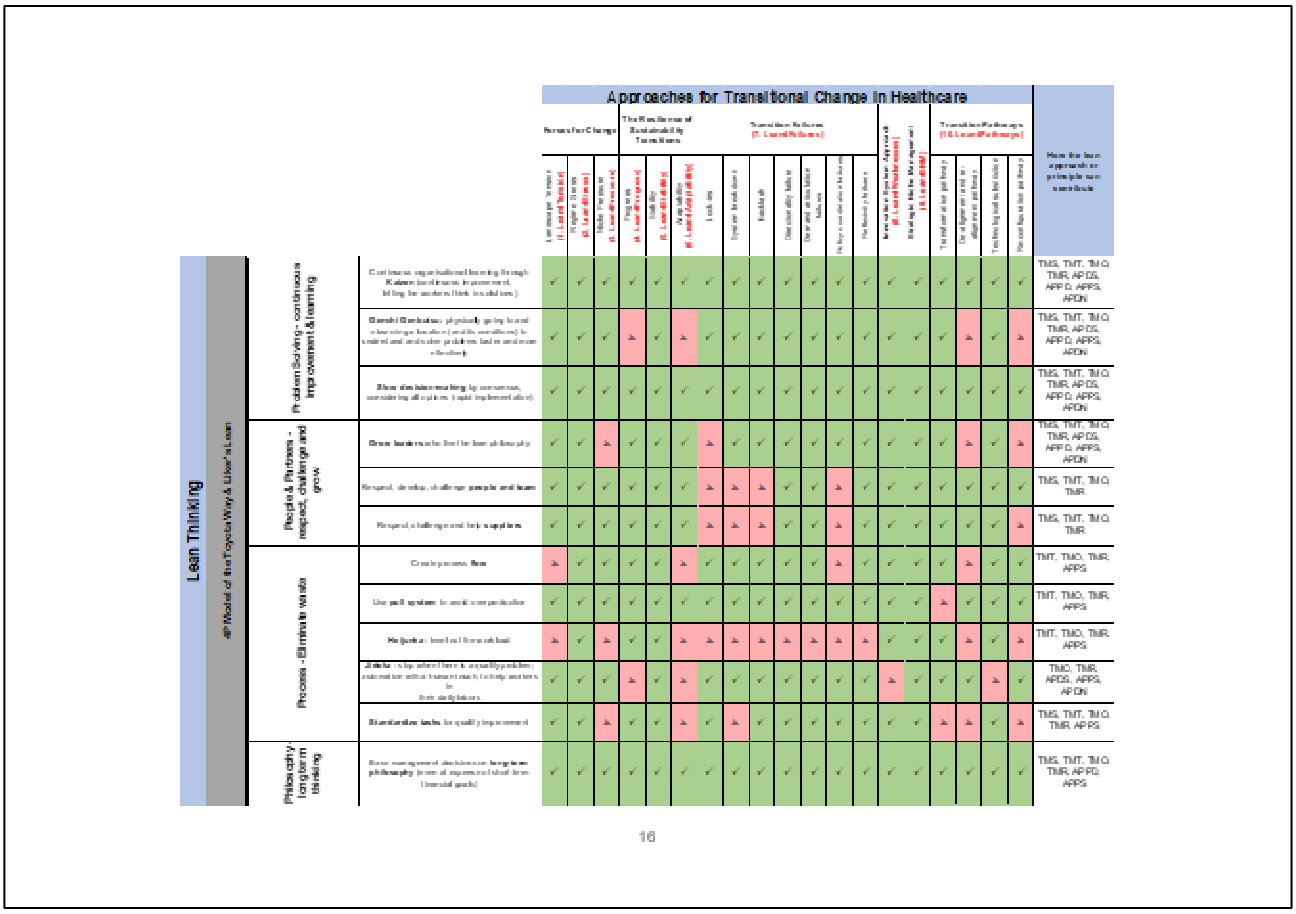
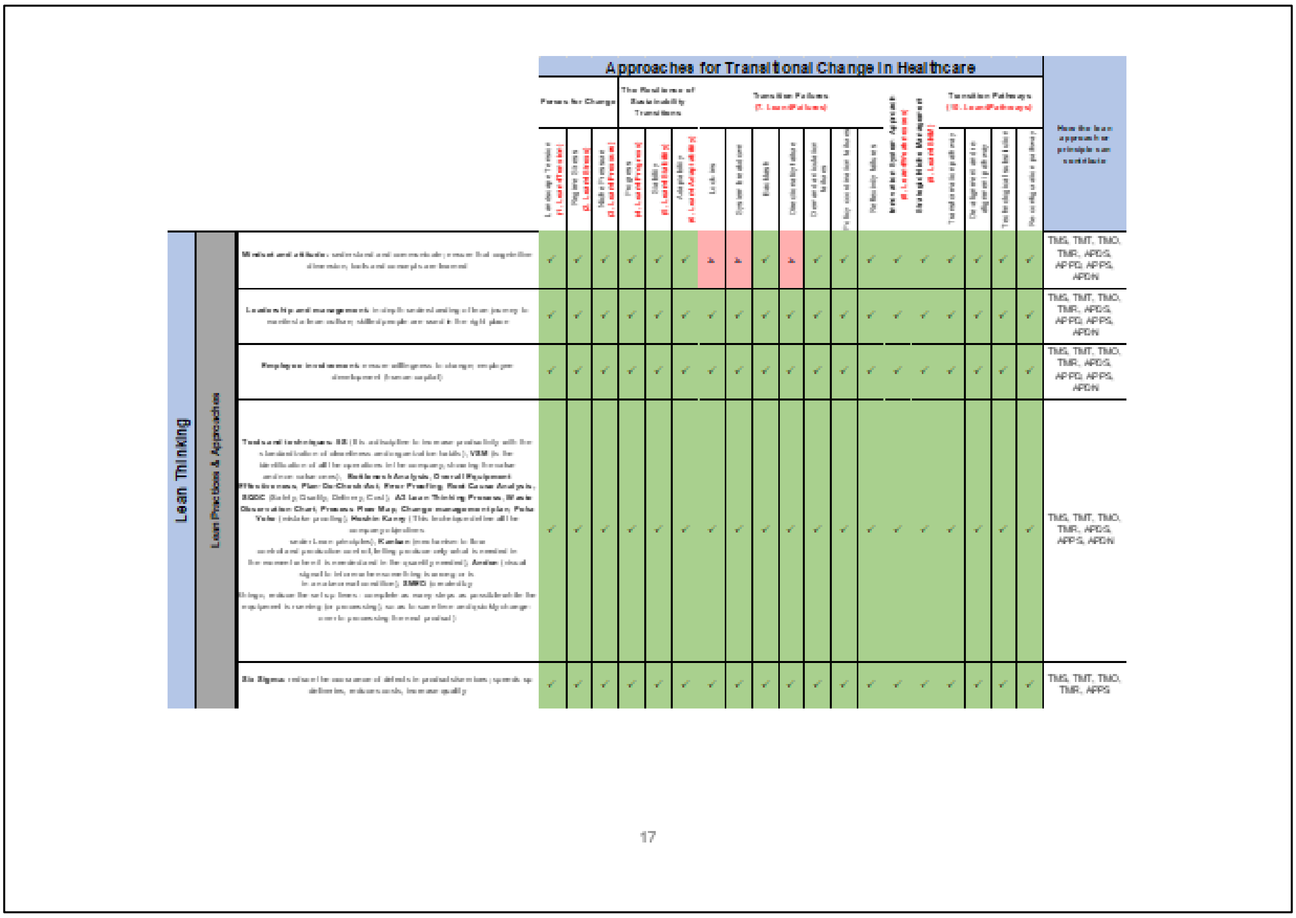

Approaches for Transitional Change in Healthcare
Forces for Change
The Resilience of Sustainability Transitions
Transition Failures
Transition Pathways
How the lean approach or principle can contribute
Lean Thinking
4P Model of the Toyota Way & Liker's Lean
Problem Solving - continuous improvement & learning
People & Partners - respect, challenge and grow
Process - Eliminate waste
Philosophy - long term thinking
16


Approaches for Transitional Change in Healthcare
Forces for Change
The Resilience of Sustainability Transitions
Transition Failures
Transition Pathways
How the lean approach or principle can contribute
Lean Thinking
Lean Practices & Approaches
17

Lean Thinking – Lean Principles			Forces for Change: Landscape Tension (1. Lean4Tension)	Forces for Change: Regime Stress (2. Lean4Stress)	Forces for Change: Niche Pressure (3. Lean4Pressure)	The Resilience of Sustainability Transitions: Progress (4. Lean4Progress)	The Resilience of Sustainability Transitions: Stability (5. Lean4Stability)	The Resilience of Sustainability Transitions: Adaptability (6. Lean4Adaptability)	Transition Failures (7. Lean4Failures): Lock-ins	Transition Failures: System breakdown	Transition Failures: Backlash	Transition Failures: Directionality failure	Transition Failures: Demand articulation failure	Transition Failures: Policy coordination failure	Transition Failures: Reflexivity failure	Innovation Systems Approach (8. Lean4Weaknesses)	Strategic Niche Management (9. Lean4SNM)	Transition Pathways (10. Lean4Pathways): Transformation pathway	Transition Pathways: De-alignment and re-alignment pathway	Transition Pathways: Technological substitution	Transition Pathways: Re-configuration pathway	How the lean approach or principle can contribute
L1	Reducing/ Eliminating activities that do not add value	S1: Reduce resources S10: Increase capacity of reuse, remanufacture and recondition	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L2	Reducing uncertainty	S1: Reduce resources S2: Time efficiency S11: Reduce energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L3	Focus on customer requirements	S2: Time efficiency S3: Reduce waiting time S6: Support community activities	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L4	Reduce cycle time	S1: Reduce resources S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L5	Simplifying the process	S3: Reduce waiting time S9: Increase recycling capacity S11: Reduce energy consumption S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	x	✓	x	x	✓	x	✓	✓	x	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L6	Increase production flexibility	S9: Increase recycling capacity S10: Increase capacity of reuse, remanufacture and recondition S11: Reduce energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L7	Increase process transparency	S1: Reduce resources S2: Time efficiency S11: Reduce energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS

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Lean Thinking – Lean Principles			Forces for Change: Landscape Tension (1. Lean4Tension)	Forces for Change: Regime Stress (2. Lean4Stress)	Forces for Change: Niche Pressure (3. Lean4Pressure)	The Resilience of Sustainability Transitions: Progress (4. Lean4Progress)	The Resilience of Sustainability Transitions: Stability (5. Lean4Stability)	The Resilience of Sustainability Transitions: Adaptability (6. Lean4Adaptability)	Transition Failures (7. Lean4Failures): Lock-ins	Transition Failures: System breakdown	Transition Failures: Backlash	Transition Failures: Directionality failure	Transition Failures: Demand articulation failure	Transition Failures: Policy coordination failure	Transition Failures: Reflexivity failure	Innovation Systems Approach (8. Lean4Weaknesses)	Strategic Niche Management (9. Lean4SNM)	Transition Pathways (10. Lean4Pathways): Transformation pathway	Transition Pathways: De-alignment and re-alignment pathway	Transition Pathways: Technological substitution	Transition Pathways: Re-configuration pathway	How the lean approach or principle can contribute
L8	Controlling the entire process	S7: Train human resources S10: Increase capacity of reuse, remanufacture and recondition S11: Reduce energy consumption S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L9	Improving the process continuously	S1: Reduce resources S4: Monitor fixed cost S9: Increase recycling capacity S11: Reduce energy consumption S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L10	Gathering information about competitors	S5: Stakeholder involvement in strategic decisions	✓	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APOS, APPO, APPS, APON
L11	Reduction of raw materials	S1: Reduce resources S4: Monitor fixed cost S12: Reduce Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	✓	x	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS
L12	Efficient allocation of human resources	S1: Reduce resources S5: Stakeholder involvement in strategic decisions S6: Support community activities S7: Train human resources S8: Corporate Social Responsibility (CSR)	✓	✓	✓	✓	✓	✓	x	✓	✓	x	✓	x	x	✓	x	✓	✓	✓	✓	TMS, TMT, TMO, TMR, APPS

Figure 5: Lean, Sustainability Transitions in Healthcare Synthesis

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3 REQUIREMENT SPECIFICATIONS FOR RESEARCH PRODUCT DEVELOPMENT

This section highlights and discusses the five distinct requirement types that are required during the development phase of the systems engineering approach.The distinct requirements will be identified within each of the five requirement types mentioned and defined in section 4.1. Aken's requirement specification types have been used as a guide to identify and develop the requirement specifications.

3.1 FUNCTIONAL REQUIREMENTS (FR):

The functional requirements are the specifications which developed research product has to deliver in terms of performance. These specifications stipulate the requirements for the optimal performance of the research product. As previously discussed, it is expected that the research product should contribute towards knowledge gaps and disconnection as highlighted in Section 3 in order to contribute positively towards fulfilling the aim of this research given the findings in the literature. Functional requirements for the research product are:

i. the research product should sufficiently integrate lean thinking into sustainability transitions in healthcare; and
ii. the research product should approach sustainability transitions from a sociotechnical transition perspective; and
iii. the research product should incorporate an understanding of sustainability transitions in healthcare within a holistic context; and
iv. the research product should apply to societal systems.

3.2 USER REQUIREMENTS (UR):

The user requirements denote specifications from the viewpoint of the user. Systems engineering provides guidelines for the development of user requirements. It is expected that the research product adheres to the following user requirements:

i. the research product should be understandable and unambiguous; and
ii. the research product should be clear and concise; and
iii. the research product should be open-ended to allow for further discussions from various viewpoints, disciplines and contexts; and
iv. the research product should be accompanied by practical implementation strategies and utility as it is developed from an engineering perspective.

3.3 DESIGN RESTRICTIONS (DR):

The design restrictions discuss the preferred solution space for the research product. Sociotechnical transitions have been included in the research, but the research was mostly conducted from a multi-discipline perspective. Given that the author conducted the study from an engineering perspective, the research product is expected to have the following design restrictions:

i. the research product is developed from an Industrial Engineering perspective as it is the discipline of this research. Other inputs from other disciplines could be added by SMEs in specific fields pertaining to the research; and
ii. the research product does not provide new meaning or theory around lean thinking and sustainability transitions. However, it integrates lean thinking into sustainability transitions in healthcare using theory and examples provided through literature resources; and
iii. the research product exclusively implements a sociotechnical transition perspective towards sustainability transitions.

3.4 ATTENTION POINTS (AP):

The attention points are those requirements that need to be addressed during the development of the research product. The attention points for the research product are:

i. the research product should serve as a guide in academic research about the key topics of this research, being lean thinking implementation to facilitate and/or support sustainability transitions in healthcare; and
ii. the research product's guidelines and solutions should not exceed the required limit of expectations; and
iii. the research product should be used when certain sustainability needs are identified and highlighted; and
iv. the research product may be the approach to attaining a deeper understanding of the development of novel sustainability transitions that include lean thinking.

3.5 BOUNDARY CONDITIONS (BC):

The boundary conditions stipulate the restrictions that have to be met for the research product to work as initially intended during the development of the research product. The research product is developed on a high level discussing the analysis of the integration of lean thinking and sustainability transitions. It, therefore, aims to add support to further research. Given this premise, the boundary conditions for this research product is:

i. the research product is most appropriate for the application to healthcare systems in the quest to fulfil sustainability targets and overcome challenges experienced in healthcare; and
ii. the research product must be utilised by users with some basic prior knowledge of the concepts at hand; and
iii. the research product cannot be applied without any contextual contributions from the users; and
iv. the research product is exploratory in the application and is not to be used as a prescribed method in the integration of lean thinking in sustainability transitions in healthcare.

4. RESEARCH PRODUCT

The conceptual framework, as illustrated in Figure 6, provides a summarised version of the overarching approach to the identified problem of this research. A more in-depth (preliminary) framework operationalisation is provided in the following section.

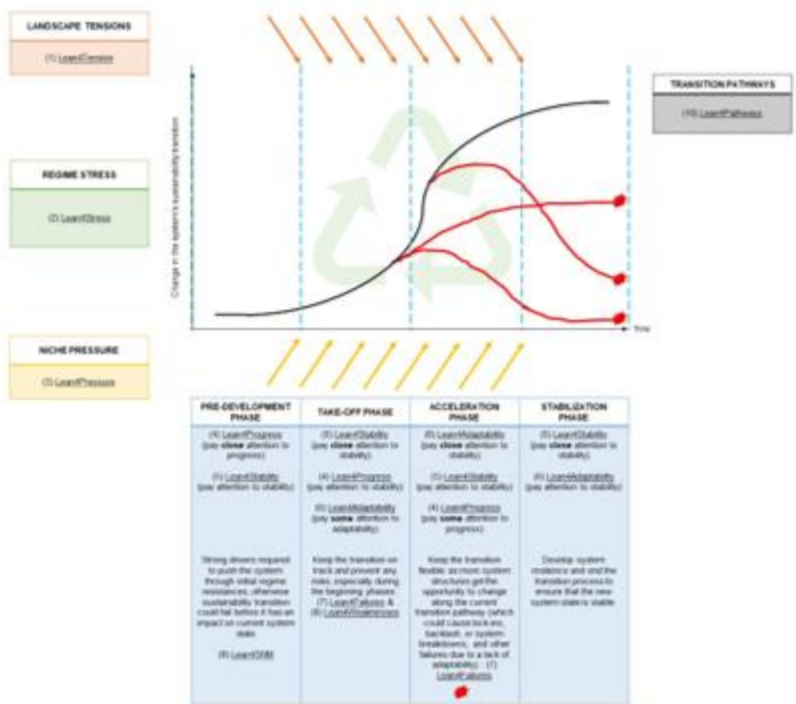

Figure 6: LT4ST Tool - Conceptual Framework

4.1 PRELIMINARY OPERATIONALISATION PHASES AND STEPS

The LT4STHC framework consists of four phases, i.e. Phase 1, which pertains to the investigation and analysis of the sustainability transition in healthcare; Phase 2, which pertains to the identification of the aspect or phase in the sustainability transitions that requires support in order for the sustainability transitions to move on to the next phase in the transition; Phase 3, which pertains identifying which lean thinking approach or principle could be used to support the identified aspect of phase in the sustainability transitions that requires support; and Phase 4, which pertains to the strategising of a plan of action to implement the identified lean thinking approach or principle to support sustainability transitions in healthcare.

PHASE 1:

This phase consists of investigating and analysing the sustainability transition in healthcare.

<u>Step 1</u> – UNDERSTAND AND DETERMINE THE AIM AND PURPOSE OF THE SUSTAINABILITY TRANSITION IN HEALTHCARE

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Make use of the '*Socio-technical Systems Theory*' [1] to understand the healthcare system.

Conduct an '*As-Is Analysis*' [2] to determine the current state of the sustainability transition in healthcare systems. This can either focus on the entire system or on one or more specific processes within the system.

Step 2 - USE ANALYTICAL APPROACHES TO INVESTIGATE AND ANALYSE SUSTAINABILITY TRANSITION IN HEALTHCARE

Conduct a '*To-Be* Analysis' [3] to determine the future state to describe the desired output in terms of how the system processes, culture and capabilities will appear in the future.

Using various analytical tools and approaches to investigate sustainability transitions in healthcare. These analytical tools and approaches such as '*MLP*' [4] will assist in understanding the complex dynamics of socio-technical change (i.e. sustainability transition).

Complete a '*Gap Analysis*' [5] to determine where the system is within the sustainability transition and where it would like to be.

PHASE 2:

This phase consists of identifying which aspect or phase of the sustainability transition in healthcare requires support.

Step 3 - DETERMINE THE CAUSE OF THE HINDRANCE

Conducting a '*Root Cause Analysis*' [6] to discover the cause of why the aspect or phase in the sustainability transition is lacking, and thus not allowing the sustainability transition to progress to the next phase (causing a hindrance to the 'flow' of the sustainability transition in healthcare).

Step 4 – IDENTIFY WHICH ASPECT OR PHASE OF THE SUSTAINABILITY TRANSITION REQUIRES SUPPORT

Determine the transition phase in which the problem occurs i.e. predevelopment, take-off, acceleration, and/or stabilization, by using the results of the '*Root Cause Analysis*' as conducted in Step 3.

PHASE 3:

This phase consists of determining which lean thinking approach or principle could support the identified aspect or phase.

Step 5 – LT4ST TOOL

Utilize the '*LT4ST Tool*' [7] to identify which lean thinking approach or principle could be used to support sustainability transitions in healthcare.

The LT4STHC framework will be the approach to assist in determining the required lean thinking approaches and principles that can be implemented in order to ensure that the sustainability transition has no hindrances, and thus 'flows' without any disruptions.

PHASE 4:

This phase consists of determining a plan of action for the implementation of the identified lean thinking approach or principle that could support the aspect or phase in the sustainability transition in healthcare that requires attention in order for the sustainability transition to flow.

Step 6 – ENSURE SUSTAINABILITY TRANSITION 'FLOW'

Discuss and determine why and how the identified lean thinking approach or principle (as determined by making use of the '*LT4ST Tool*') can support the identified hindrance in the sustainability transition in healthcare, which will thus assist in ensuring the success of a sustainability transition in healthcare.

***Please complete the 'SME Questionnaire' now.**

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Figure 49: Verification questionnaire

PLEASE FILL IN THE FOLLOWING INFORMATION:

Participant name (No personal information will be shared in any phase of the research product):

____

Sector:____

Occupation:____

Background:____

Participant's knowledge and insight		**Participant's response**	
Questions based on the participant's knowledge of the literature overview provided		**Please answer 'Yes' or 'No'**	**Comments**
1	Are you familiar with lean implementation in healthcare?		
2	Are you familiar with the reasons for considering lean thinking to support sustainability transitions in healthcare?		
3	Are you familiar with the phases of a sustainability transition?		
4	Are you currently working in the healthcare industry?		
5	Are you currently directly involved in lean implementation in healthcare?		

INTRODUCTION

This document includes a questionnaire for the verification of the LT4STHC framework and LT4ST tool, and appendices to which the questions in the questionnaire refer. An overview document is supplied separately for the participants.

The questionnaire is divided into three sections:

Section 1 – This part applies to Session 1 of the stakeholder engagement which is concerned with the verification of the literature that was used to develop the LT4STHC framework and LT4ST tool.

Section 2 – The second part applies to Session 2 of the stakeholder engagement. The second part of the questionnaire is concerned with the verification of the LT4STHC framework and LT4ST tool development process.

Section 3 – The third part also applies to Session 2 of the stakeholder engagement and is concerned with the verification of the high-level structure and methodology of the LT4STHC framework and LT4ST tool.

1. VERIFICATION OF LITERATURE USED TO DEVELOP THE MODEL

Required knowledge from SME: Sustainability, healthcare, and/or lean implementation.

The following questions aim to verify the literature (specifically the novel literature that is a new contribution by the author to the body of literature) that was used to develop the framework and tool.

The literature used to develop the model		
Open-ended verification questions		**Answer**
Forces and Conditions for Transitional Change		
1.1	Elaborate on your thoughts with regard to the sustainability transition approaches of **Forces and Conditions for transitional change** (refer to Chapter 2.1 of the document).	
1.2	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach.	
1.3	Would you propose an alternative/ better sustainability transition strategy?	
Transition and Transformational Failure		
1.4	Elaborate on your thoughts with regard to the sustainability transition approaches of **Transition and Transformational Failures** (refer to Chapter 2.1 of the document).	
1.5	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach	
1.6	Would you propose an alternative/ better sustainability transition strategy?	
Innovation System Approach		
1.7	Elaborate on your thoughts with regard to the sustainability transition approaches and **Innovation System Approach** (refer to Chapter 2.1 of the document)	
1.8	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach	
1.9	Would you propose an alternative/ better sustainability transition strategy?	
Strategic Niche Management		
1.10	Elaborate on your thoughts with regard to the sustainability transition approaches of **Strategic Niche Management** (refer to Chapter 2.1 of the document)	
1.11	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach	
1.12	Would you propose an alternative/ better sustainability transition strategy?	
Transition Management		

1.13	Elaborate on your thoughts with regard to the sustainability transition approaches of **Transition Management** (refer to Chapter 2.1 of the document)	
1.14	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach	
1.15	Would you propose an alternative/ better sustainability transition strategy?	
	The Resilience of Sustainability Transitions	
1.16	Elaborate on your thoughts with regard to the sustainability transition approaches of **'The Resilience of Sustainability Transitions'** (refer to Chapter 2.1 of the document).	
1.17	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach	
1.18	Would you propose an alternative/ better sustainability transition strategy?	
	Transformation Pathways	
1.19	Elaborate on your thoughts with regard to the sustainability transition approaches of **'Transformation Pathways'** (refer to Chapter 2.1 of the document).	
1.20	Explain what you consider the key strengths and key weaknesses of this sustainability transition approach	
1.21	Would you propose an alternative/ better sustainability transition strategy?	
	4P Model of the Toyota Way & Likers Lean model	
1.22	Elaborate on your thoughts with regard to the lean thinking approach of the '4P Model of the Toyota Way & Likers Lean model (refer to Chapter 2.2 of the document).	
1.23	Explain what you consider the key strengths and key weaknesses of this lean thinking approach	
1.24	Would you propose an alternative/ better lean thinking approach?	
	Lean Practices and Approaches	
1.25	Elaborate on your thoughts with regard to the lean thinking approach of the 'Lean practices and approaches' (refer to Chapter 2.2 of the document).	
1.26	Explain what you consider the key strengths and key weaknesses of this lean thinking approach.	
1.27	Would you propose an alternative/ better lean thinking approach?	
	Lean Principles and Sustainability Principles	
1.28	Elaborate on your thoughts with regard to the lean thinking approach of the 'Lean principles and sustainability principles' (refer to Chapter 2.2 of the document).	

1.29	Explain what you consider the key strengths and key weaknesses of this lean thinking approach.	
1.30	Would you propose an alternative/ better lean thinking approach?	

2. VERIFICATION OF THE DEVELOPMENT PROCESS

Required knowledge from SME: Sustainability, healthcare, and/or lean implementation.

The following questions aim to verify the development process for the LT4STHC framework and LT4ST tool.

The development process of the framework and tool		
Open-ended verification questions		Answer
2.1	Do you think the development process and the design decisions contribute to addressing the development and purpose of the framework and tool?	
2.2	What do you consider the key strength and key weaknesses of the development process?	
2.3	Would you suggest an alternative development process?	
2.4	Do you think that the design decision is sufficient to develop a framework and tool? (With the aim of identifying lean thinking approaches and tools to support sustainability transitions in healthcare).	
2.5	Do you think the LT4ST tool will achieve its stated purpose (i.e., to identify lean thinking approaches and principles that could support sustainability transitions in healthcare)? (Refer to chapter 4 in the document)	
2.6	What do you consider the key strengths of the LT4ST tool?	
2.7	What do you consider the key weakness of the LT4ST tool?	
2.8	What alterations would you make to the LT4ST tool?	
2.9	Where do you think the model would fail in its intended purpose?	

3. VERIFICATION OF PROPOSED PRELIMINARY LT4STHC FRAMEWORK HIGH-LEVEL STRUCTURE AND METHODOLOGY

Required knowledge from SME: Sustainability, healthcare, and/or lean implementation.

This research **aims** to use lean thinking to support sustainability transitions in healthcare systems. This aim is achieved by developing the lean thinking for sustainability transitions in healthcare (LT4STHC) framework, which uses the author's developed tool (LT4ST tool) to determine which lean thinking approaches or principles could be used to support specific aspects of sustainability transitions in healthcare.

The structure of the LT4STHC framework and tool							
Close-ended verification questions		Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Comments
3.1	The purpose of the framework fits the aim of this study (refer the chapter 4.1 of the document)						
3.2	The layout of the high-level structure makes the framework easy to understand.						
3.3	The layout of the methodology makes the conceptual framework easy to understand. (LT4ST Tool)						
3.4	The phases of the methodology aim to achieve the overall purpose of the framework.						
3.5	It is necessary to illustrate the inputs and outputs of the methodology.						
3.6	It is necessary to illustrate the user level that reflects the steps the user should follow to utilise the framework.						
3.7	The steps explained to						

	provide a clear understanding of how the model should be used.						
Open-ended verification questions		Answer					
3.8	Do you think the literature used to develop the LT4STHC framework and LT4ST tool is sufficient?						
3.9	What do you consider to be the key strengths of the LT4STHC framework and LT4ST tool?						
3.10	What do you consider the limitations of the LT4STHC framework and LT4ST tool?						
3.11	Where do you think the LT4STHC framework and LT4ST tool would fail, if implemented?						

Figure 50: Validation questionnaire

Personal Information:

Name & Surname:

____________________________________(will not be shared during any phase of the research project).

Qualifications & Institution where qualifications were obtained:

____

Current job title/description:

____

Questions:

No	To which extent do you agree that:	Likert Scale Rating				
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	you have knowledge and experience with using lean thinking to support sustainability transitions in healthcare.					
2	the requirement specifications (Chapter 3 of this document) and methodology effectively and adequately contribute to the research product.					
3	the research product (Chapter 4 of this document) sufficiently articulates the incorporation and orientation of the elements of lean thinking and sustainability transitions in healthcare.					
4	the research product developed in this research supports sustainability transitions in healthcare by using lean thinking.					
5	considering the terminology and operability, the research product is easy to use and intuitive to understand.					
6	the user of the research product does not require a very high level of experience or knowledge on using lean thinking to facilitate and/or support sustainability transitions in healthcare.					

7	the research product could apply to any existing healthcare system.					
Open-ended questions:						
8	What do you view as some of the key strengths of the research product?					
9	What do you view as some of the key weaknesses of the research product?					
10	Are you aware of any other system, research product, framework, etc. with which this research product could be used?					
11	Are there any literature sources that you believe could have been overlooked, but should be considered for this research?					
12	Any additional comments:					