# Theorising and Testing the Underpinnings of Lean Six Sigma

A thesis submitted in partial fulfilment of the requirements for the degree of

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**Achinthya Dharani Halnetti Perera**

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# ABSTRACT

Lean Six Sigma (LSS) is a widely used business process improvement method that combines Lean and Six Sigma. Despite its popularity and large volumes of research, the theoretical underpinnings of LSS remain underdeveloped. This thesis explores the theoretical foundations and practical implications of LSS, using an LSS project as the unit of analysis. Research objectives include: (i) identifying and operationalising the determinants of LSS, (ii) hypothesising the relationships between the determinants of LSS in predicting and explaining LSS project performance and testing the hypothesis empirically, (iii) assessing the impact of residual risks on LSS project performance, (iv) interpreting theoretical relationships from a practical perspective, and (v) testing whether LSS fits to nonmanufacturing as well as it would to manufacturing at a theoretical level. To achieve the objectives, a conceptual model was first framed by conducting a comprehensive literature review on available theories of SS/LSS and a novel approach (machine learning) to extract essential elements from the literature on critical success factors (CSFs). The conceptual model was then developed into a testable theoretical model through case research, which facilitated the operationalisation of the theoretical constructs. The overall hypothesis underpinning the theoretical model states, "Leadership engagement drives LSS Project Initiation and the Continuous Improvement Culture to execute an LSS project to yield the desired outcomes, but the Project Execution → Project Performance causal link would be moderated by the project residual risk". Finally, the theory was empirically tested using partial least squares structural equation modelling based on data from 296 organisations worldwide. Although the data supported the overall hypothesis, some individual paths failed to support the model ($p > 0.05$). For example, project residual risk did not moderate the impact as anticipated, indicating that risk assessment is given significant attention during LSS project initiation. The total effect of Leadership Engagement on LSS Project Outcomes was 0.216 ($p < 0.001$), implying its practical importance (medium effect). The model fitted to nonmanufacturing equally well as manufacturing, supporting the hypothesis. Although case studies suggested that LSS projects are defined differently in manufacturing and nonmanufacturing and LSS structure differs from context to context, the model is robust enough to provide a solid theoretical foundation for LSS. The study adds to the current body of knowledge as a theory extension to the field of quality and operations management.

Keywords: Lean Six Sigma, Project Lens, Continuous Improvement, Partial Least Squares Structural Equation Modelling

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1. Perera, A. D., Jayamaha, N., Grigg, N. P., & Tunnicliffe, M. (2021a). Lean six sigma through an Australasian lens: project definition, structure and practices. International Journal of Lean Six Sigma. https://doi.org/10.1108/ijlss-07-2021-0132

2. Perera, A. D., Jayamaha, N. P., Grigg, N. P., Tunnicliffe, M., & Singh, A. (2021b). The Application of Machine Learning to Consolidate Critical Success Factors of Lean Six Sigma. IEEE Access, 9, 112411-112424. https://doi.org/10.1109/ACCESS.2021.3103931

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AHP | Analytical hierarchy process |
| AI | Artificial intelligence |
| ANOVA | Analysis of variance |
| ANZSIC | Australian and New Zealand Standard Industrial Classification system |
| AU | Australia |
| AVE | Average variance extracted |
| BC | Boundary conditions |
| BCE | Binary cross-entropy |
| CB-SEM | Covariance based structural equation modelling |
| CFA | Confirmatory factor analysis |
| CI | Continuous improvement |
| CICUL | Continuous Improvement Culture |
| CMB | Common method bias |
| Cpk | Process capability index |
| CR | Composite reliability |
| CSF | Critical success factor |
| CSV | Cross validation |
| DC | Development Culture |
| DEMATEL | Decision-Making Trial and Evaluation Laboratory |
| DL | Deep learning |
| DMAIC | Define-Measure-Analyse-Improve-Control |
| DNN | Deep neural networks |
| DPMO | Defects per million opportunities |
| EFA | Exploratory factor analysis |
| FMEA | Failure modes and effects analysis |
| FN | False negative |
| FP | False positive |
| GB | Green Belt |
| GC | Group culture |
| GE | General Electric |
| HC | Hierarchical Culture |

| | |
|---|---|
| HRM | Human resource management |
| HTMT | Heterotrait-monotrait ratio of correlations |
| IEQMS | Integrated Educational Quality Management System |
| ISM | Interpretive structural modelling |
| JIT | Just in time |
| JOM | Journal of Operations Management |
| KPI | Key performance indicator |
| LE | Leadership Engagement |
| LSS | Lean six sigma |
| LSSBB | Black Belt |
| LSSMBB | Master Black Belt |
| LSSPER | LSS Performance |
| MAR | Missing at random |
| MCAR | Missing completely at random |
| MGA | Multigroup analysis |
| MICMAC | Matriced Impacts Croisés Multiplication Appliquée à un Classement |
| MICOM | Measurement invariance by means of composite models |
| MIT | Massachusetts Institute of Technology |
| ML | Machine learning |
| MO | Manufacturing organisation |
| NLP | Natural language processing |
| NMO | Nonmanufacturing organisation |
| NN | Neural network |
| NZ | New Zealand |
| OLS | Ordinary least squares |
| PACAP | Potential absorptive capacity |
| PCA | Principal component analysis |
| PDCA | Plan-Do-Check-Act |
| PLS-SEM | Partial least squares structural equation modelling |
| PMS | Parallel meso-structure |
| PREX | LSS Project Execution |
| PRIN | LSS Project Initiation |
| PRISMA | Preferred reporting items of systematic reviews and meta-analyses |

| | |
|---|---|
| PRRISK | Project Residual Risks |
| QMS | Quality management system |
| RACAP | Realised absorptive capacity |
| RC | Rational Culture |
| ReLu | Rectified linear units |
| RMSE | Root mean square error |
| RQ | Research question |
| SEM | Structural equation modelling |
| SMEs | Small and medium enterprises |
| SML | supervised machine learning |
| SPC | Statistical process control |
| SS | Six sigma |
| STS | Sociotechnical systems |
| TMC | Toyota motor corporation |
| TP | True positive |
| TN | True Negative |
| TPM | Total predictive maintenance |
| TPS | Toyota production system |
| TQM | Total quality management |
| TW | Toyota way |
| US | United State |
| VIF | Variance inflation factors |
| YB | Yellow Belt |

# CHAPTER 1
# INTRODUCTION

## 1.1 Research Background

Exponential growth of customer demand for high quality products and services with speedy delivery, and increased competition due to globalisation, have forced organisations to explore profitable solutions to gain competitive advantage (Adikorley et al., 2017; Alhuraish et al., 2017). Organisations across the globe have embraced various business and operational strategies to optimise their productivity and customer satisfaction (Antony et al., 2017b; Fullerton et al., 2014). Lean Six Sigma (LSS) has emerged as a prominent approach for optimising processes and driving continuous improvement (CI) across industries around the world (Antony et al., 2018; Assarlind et al., 2013). LSS integrates the principles of Lean, focused on eliminating non-value-added activities, with the statistical rigor of Six Sigma (SS), aimed at reducing process variation and defects (Arnheiter & Maleyeff, 2005; Liker, 2004). Both Lean and SS insist on customer focus and CI. However, as standalone methodologies, each focuses on various aspects of CI. Combining Lean with SS within a unified framework (i.e., LSS) is said to offer a systematic and more versatile framework for critical-to-quality and critical-to-process improvements via a data-driven approach to problem-solving (Assarlind et al., 2013; Patel & Patel., 2021; Rodgers & Antony, 2019). The extensive adoption of LSS in diverse sectors over two decades suggests that LSS is a widely used operations management strategy or approach (Antony et al., 2017a; Perera et al., 2021b; Price et al., 2018).

The history of Lean production dates back to the post-World War II era, marking a significant shift in manufacturing and operational practices. (Holweg, 2006; Shah & Ward, 2003; (Holweg, 2006; Shah & Ward, 2003; Womack & Jones, 1994). In response to the economic recession following World War II, manufacturing industries urgently required innovative solutions to enhance efficiency and resilience. Hence, innovative approaches were needed, such as Henry Ford's innovative assembly line that focused on improving efficiency, reducing waste, and enhancing overall operational resilience (Hozak & Olsen, 2015; Vamsi Krishna Jasti & Kodali, 2014). These circumstances led to the evolution of Lean as a transformative philosophy that revolutionised how industries approach production and paved the way for streamlined and sustainable manufacturing practices. The term ‘Lean’ was first coined by John Krafcik of the Sloan School of Management of the Massachusetts Institute of Technology in the United States (US) in 1988, but the concept gained traction after the publication of the book, “The machine that changed the world” by James P. Womack and his associates (Womack et al., 1990). Essentially, lean manufacturing is a Western interpretation of the Japanese concept of continuous improvement, epitomised by the Toyota Production System (TPS) (Antony et al., 2003a; Antony et al., 2017a; George, 2002; Liker, 2003; Womack & Jones, 1996; Zugelder, 2012). Thus, TPS, as the foundational element of Lean, has given rise to various quality approaches such as Quality Circles, Visual Management, and Total Productive Maintenance, shaping modern Lean practices in the global manufacturing landscape (Hozak & Olsen, 2015).

Motorola developed SS around 1987 and marked a pivotal shift in process improvement and cost-effective customer satisfaction, laying the foundation for quality management reform, which was previously led by the total quality management (TQM) movement in the late 1980s (Cheng & Chang, 2012; Muir, 2006; Pepper & Spedding, 2010). Motorola’s success with SS was highlighted upon winning the prestigious Malcolm Baldrige National Quality Award in 1988, revealing SS as the key tool behind its achievements (Drohomeretski et al., 2013; Schroeder et al., 2008; Sin et al., 2015). Following Motorola’s success, many US corporate giants such as General Electric and Allied Signal also embraced SS in the late 1990s to enhance business performance by achieving significant financial savings (Sin et al., 2015). Apart from being a quality improvement approach that improves quality performance to unprecedented levels, SS can also be viewed as a performance metric representing 3.4 defects per million opportunities (DPMO) of process capability or quality performance (Desai & Prajapati, 2017); this level of performance can be achieved through an improvement in the quality and consistency of products or processes by reducing variation to a minimal level relative to allowable tolerances (Chen & Lyu, 2010). SS is thus a business strategy which aims to achieve high quality in a cost-effective manner following a team-based (but leadership driven and expert guided) systematic five-step problem solving method known as the "Define-Measure-Analyse-Improve-Control" (DMAIC) methodology (Anand et al., 2010; Antony et al., 2017a). In this study, the researcher uses the following definition of SS provided by Schroeder et al. (2008):

"Six Sigma is an organised, parallel-meso structure to reduce variation in organisational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives" (p. 540).

Schroeder et al. (2008) argue that a SS quality improvement team represents a project management-based reporting structure that runs parallel to the traditional organisational structure. Consequently, Schroeder et al. posit that organisational leadership drives strategic project selection and a problem-solving culture in the organisation for project success (apart from the structured problem-solving approach itself). Similar behavioural science-based models (e.g., goal theory-based hypotheses) have been posited by others (details are included in the literature review in Chapter 2). While these models add academic credibility to an otherwise practitioner-led discipline, review of extant literature shows that most of the SS theoretical models remain empirically untested.

Snee & Hoerl (2007) expound that while Lean focuses on reducing nonvalue added activities and waste and SS focuses on reducing variation, when the two approaches work together seamlessly, they provide the best of both worlds. Similarly, numerous authors (e.g., (e.g., Arnheiter & Maleyeff, 2005; Mustapha et al., 2019; Papic et al., 2017) have demonstrated that Lean and SS complement each other as structured methods of problem-solving. It has been argued that LSS is not merely a combination of Lean and SS methodologies, but an amalgamation and refinement of these two approaches to form a cohesive approach (Ahmed et al., 2022; Pepper & Spedding, 2010). The key focus of LSS is meant to be to increase customer value by reducing variation, increasing effectiveness, and offering solutions to overcome the limitations of Lean and SS when used separately (Albliwi et al., 2017; Antony et al., 2003b; Pepper & Spedding, 2010). While some experts assert that Lean tools and methodologies can be incorporated into SS methodology (DMAIC) to solve problems, the others contend that SS should be used to improve processes first (e.g., reduce variation and reduce defects) before using Lean practices and tools to eliminate nonvalue added activities (Mustapha et al., 2019; Sreedharan et al., 2018a).

While there is extensive literature on successful LSS implementations — for example, many publications prescribing many different critical success factors (CSFs) of LSS implementation — a considerable gap exists in reporting unsuccessful LSS projects explaining why a particular project failed and by how much. This shortage of failure reporting is likely due to the challenges of publishing failures. At present there is need to have a robust theoretical framework that can predict and explain both successful and unsuccessful LSS implementations equally well. The growth of LSS literature since 1989 (Figure 1.1), along with the increasing application of LSS in various industries over the past two decades, have resulted in a strong interest in the approach. However, the current literature primarily focuses on success stories, leaving a void in understanding the reasons behind unsuccessful implementations. Developing and validating a comprehensive model that encapsulates the theoretical underpinnings of LSS is essential to address this gap. The development of such a model would provide not only theoretical but also practical benefits, serving as a guide for the implementation of LSS in diverse sectors. Therefore, a well-constructed theoretical model of LSS is vital not only for its academic value but also for its practical utility. Organisations can use this structure to anticipate and understand the outcomes of LSS projects, facilitating decision-making that is based on strategic insights rather than mere speculation.

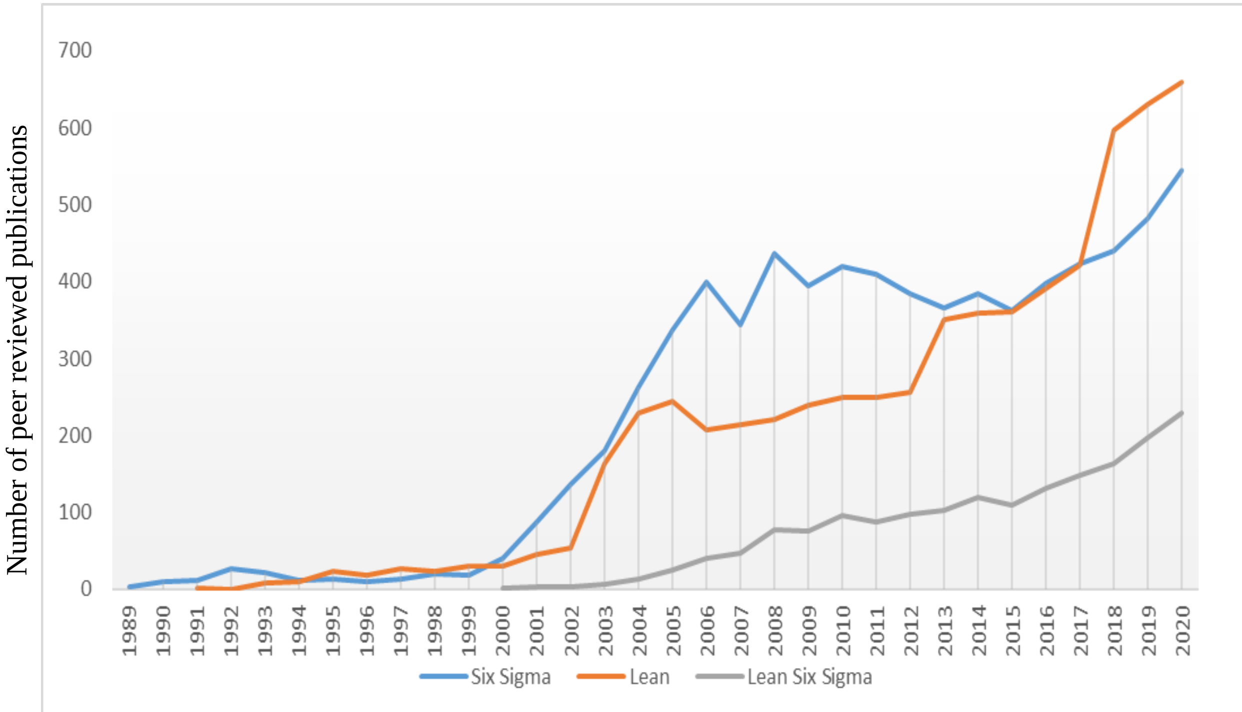


**Figure 1.1 Growth of literature of terms ''Lean'' OR ''Six Sigma'' OR ''Lean Six Sigma'' in article tiles, abstracts and keywords (Source: Perera et al., 2021b)**

## 1.2 Motives for this Research

*The primary motivator* for this research is the need for a theory on LSS in causal predictive form to predict and explain what causes a successful LSS project implementation. Questions such as what the building blocks (concepts and constructs) of LSS are and, how are they related to one another to predict and explain results, can be answered in the process of developing this causal predictive model.

*The second motivation* to launch this research is the challenges the study would pose to make it intellectually stimulating for the researcher. In formulating and testing a theory that combines Lean and SS methodologies to predict and explain achievement results, such as quality performance, the researcher faced the challenge of isolating Lean and SS from the overall quality management system (QMS) of an organisation[1]. Organisations undertake various initiatives within their QMS to enhance product and service outcomes, aligning with their quality policies and objectives. LSS is one such strategy that can be integrated into an organisation's QMS to meet these quality goals and policies. It is documented in the literature that SS is interwoven with other quality management approaches such as TQM (Schroeder et al., 2008; Zu et al., 2008), and Lean may be interwoven with other quality/operations management approaches such as agile (Piotrowicz et al., 2023; Plonka, 1997; Silva et al., 2020). Similarly, the concept of CI emphasised in TQM is interwoven with Lean's principle of pursuing perfection (Omotayo et al., 2018; Staats et al., 2011; Womack & Jones, 1994). As a result, the literature has difficulty in delineating the effects of SS/LSS from the overall quality management framework, thereby making it difficult to isolate the direct impact of LSS on performance and outcomes (Ahmed et al., 2022; Linderman et al., 2003; Uluskan & Karşı, 2022). Although not explicitly stated in the literature, researchers have attempted to circumvent this problem by presenting LSS (or SS) as a project management approach, where the focus is on the project that used LSS as the core strategy to achieve product and service results. The work of Arumugam et al. (2016), Linderman et al. (2003), and Sin et al. (2015b) are examples

[1] The American Society for quality defines a QMS as a "formalised system that documents processes, procedures, and responsibilities for achieving quality policies and objectives" (ASQ, 2023).

of work that focuses on project management rather than an overall approach to organisational management.

*The third motivation* to launch this study is the researcher seeing a novel opportunity to introduce industry 4.0 technology (artificial intelligence) to isolate the key concepts of LSS (the signal) from a plethora of prescriptive criteria on LSS implementation success, which is explained as follows:

Over the past few decades, academic and industrial research around LSS has flourished. LSS literature shows a noticeable trend, where academic efforts primarily focus on proposing CSFs for LSS implementation or analysing existing research and discussing its implications through a variety of case studies, which adds layers of sophistication to this integrated approach. In studies such as Laureani et al. (2012), Hilton et al. (2012a), Sreedharan et al. (2018a) Costa et al. (2018), and Cherrafi et al. (2016), these CSFs have been addressed emphasising their importance in understanding the determinants of the success of LSS projects. Conceptually, CSFs of LSS and the theoretical concepts that underpin LSS (i.e., LSS constructs) should be related to one another. The main challenge in synthesising the essence of LSS (i.e., the theoretical concepts or constructs) from the literature on CSFs of LSS success is the sheer number of CSFs that exist in the extant literature. Hilton et al. (2012a) identified 23 CSFs categorised under five distinct headings; Cherrafi et al. (2016) identified nine different CSFs, and many others have identified many other CSFs. It is reasonable to assume that the building blocks of LSS (in statistical or engineering terms, the *signal*) are buried under the plethora of prescriptions (CSFs) which contain some theoretical essence and substantial amounts of peripheral information (noise). Modern technology can be exploited to train computers to isolate this essence from the noise. The reader may refer to (Perera et al., 2021b) to see how this was accomplished (but it is explained in this thesis also).

*The fourth motivation* to launch the study is to know for certain whether Lean and SS have evolved from manufacturing thinking to a more generalised thinking such that LSS theory fits to nonmanufacturing as well as it does to manufacturing. Lean traditionally evolved in factories where mass production took place. Lean ideas such as pull production (Gayer et al., 2021; Koufteros, 1999), just-in-time (Monden, 2011; Williams & Butler-Jones, 2019), factory physics (Hopp & Spearman, 2011) swift and even flow (Schmenner & Swink, 1998) were originally explained using manufacturing contexts. Similarly, the SS idea of reducing the variability of a quality characteristic or defects to unprecedented levels, conducting statistically designed experiments and similar statistics heavy techniques to achieve these goals (Prashar, 2016; Taguchi & Clausing, 1990) relates to tangible goods and their associated production systems rather than to the opposite. For example, controlling manufacturing parameters to move a quality characteristic of a product to its target value, and minimise its variability around that target value to bring nonconformities/defects to a near zero level is much more straightforward than changing parameters in a service setting and expecting to bring nonconformities/defects to a near zero level. This is because the service sector is strongly associated with customers' perceptions, despite being governed by metrics (Harvey, 1998; Dabholkar, 2015; Oh & Kim, 2017 Parasuraman et al., 1985).

With the above said, of late, many more publications on Lean and SS (LSS in general) have appeared in nonmanufacturing settings. There are no signs of this trend slowing down. The recent solicitation for research on LSS within the public sector by the International Journal of Lean Six Sigma (IJLSS, 2016) indicates that LSS applications are used beyond manufacturing and service enterprises. Thus, there is sufficient grounds to test a theory on LSS across a wide variety of sectors, and thereafter, examine whether the theory fits to the nonmanufacturing sector as well as it would to the manufacturing sector.

*The fifth motivation* to launch this research stems from the concept of risk, which is inherent in any project, leave alone an LSS project. In project management literature — within and outside LSS — project complexity and project uncertainty have been posited as moderators of project outcomes (Arumugam et al., 2016; Assarlind et al., 2013; Nair et al., 2011). However, risk-based thinking is emphasised more and more in quality management literature (Chiarini, 2017; Grigg, 2021) and it is reasonable to assume that in an LSS project, project risks and risk mitigation measures would receive high priority at the project initiation stage. However, as in all projects, a residual risk would remain, and it needs to be examined whether this residual risk influences LSS project outcomes to a practically significant level.

## 1.3 Aims, Objectives of the Study

The study aims to develop and test a theoretical model that represents LSS as a management approach that results in (increased) quality performance, at an individual project level. Consequently, the study takes an LSS project as the unit of analysis.

The specific objectives of the study are as follows:

1) To identify and operationalise the determinants of LSS.
2) To develop and test a theory that predicts and explains LSS implementation and its success — or otherwise — at project level.
3) To examine whether the residual risks associated with the LSS project make any impact on LSS project performance.
4) To interpret the estimated theoretical relationships from a practical perspective.
5) To test whether the LSS model fits to nonmanufacturing as well as it would to manufacturing at a theoretical level.

## 1.4 Research Questions

The research questions serve as the guiding beacons that set the course for the investigation, providing insight into the research process (Ballenger, 2007). Research questions occur because of identifying gaps in existing literature, curiosity about phenomena, or a desire to solve problems (Ballenger, 2007; Bryman, 2016). Section 1.2 provided motives for this research. The reader may consider section 1.2 as a concise version of knowledge gaps that the literature review uncovered. The research questions that provide the direction for conducting the research to fill the knowledge gaps are as follows:

***RQ1:*** What are the determinants that predict and explain how quality performance is achieved by implementing LSS?

***RQ2:*** What are the project-related risk factors that moderate LSS project success?

***RQ3:*** Does LSS fit to the nonmanufacturing sector as well as it would to the manufacturing sector?

**RQ1** prompts the researcher to uncover the theoretical underpinnings of LSS. The constructs of LSS, their hypothesised relationships, hypothesis test results, and the boundaries within which the hypothesised relationships ought to exist are all part of answering RQ1. Therefore, RQ1 serves as the main research question of this study because RQ1 has the greatest potential to add new knowledge.

**RQ2** prompts the researcher to examine how the concept "risk" is incorporated in LSS projects and to what extent the remaining risk identified after project implementation (i.e., residual risks) affect LSS project outcomes. If risk identification and risk mitigation are considered thoroughly in LSS projects, the expectation is that while the residual risk may show a statistically significant attenuating effect on LSS project outcomes ($p < 0.05$), this does not materially affect LSS project outcomes.

**RQ3** is meant to examine whether LSS has evolved to such an extent that the theory uncovered by the researcher — more technically precisely, her theoretical model — fits to nonmanufacturing settings as well as it does to manufacturing. If the answer to RQ3 returns as a "No" it becomes possible to examine what the weak links are for nonmanufacturing. If the answer to RQ3 returns as a "Yes", the findings become useful in providing further evidence to the widely held practitioner view that LSS works well in services and other nonmanufacturing settings as it does in manufacturing. The nexus between the research questions as well as the research objectives are shown in Figure 1.2.

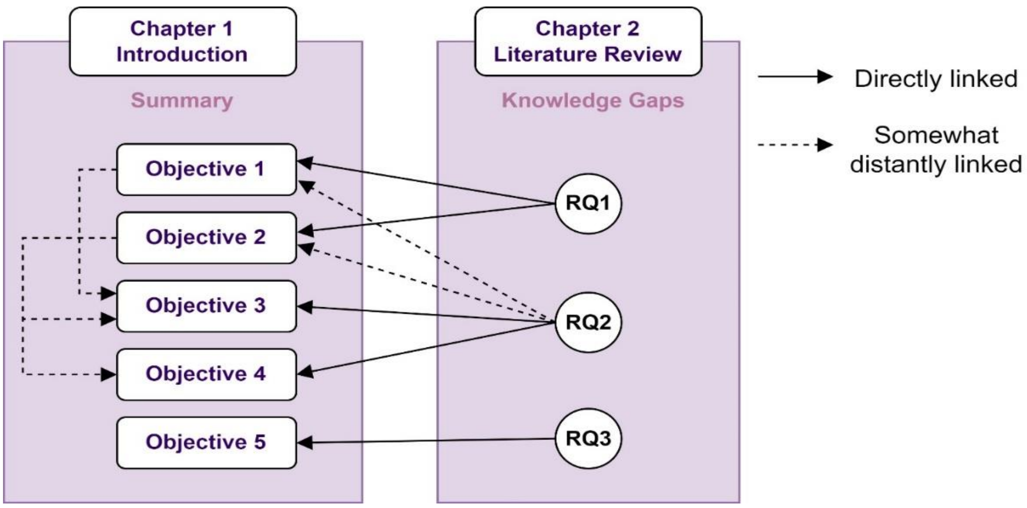


**Figure 1.2 Nexus between research questions and research objectives**

## 1.5 Novelty of the Study

The study brings novelty at least in two ways.

### 1.5.1 Novelty in the Theoretical Model

Existing theorisations of LSS (not SS) posit that LSS implementation results in quality performance because of the application of Lean practices and SS practices (e.g., Ahmed et al., 2022; Muraliraj et al., 2020; Sim et al., 2021). The researcher is not challenging these propositions. However, for these practices to take place certain behavioural elements must exist. The researcher attempted to provide a more complete understanding of LSS implementation by incorporating behavioural elements into the practice aspect to explain how LSS works from the inception of the project idea to project completion in a quality improvement project. The researcher drew inspirations from TQM theory (e.g., the role of leadership) and existing theorisation of SS (e.g., the project focus) to provide this more complete understanding of LSS. The terms quality, and quality performance are used by the researcher in this thesis not only to mean superior product or service quality, but other performance outcomes (this is particularly emphasised in Lean) leading to customer value creation.

### 1.5.2 Novelty in the Methods

The researcher observed that a great deal of peer-reviewed research (perhaps research that is more useful to the practitioner) in the form of prescriptions of numerous CSFs of LSS implementation success is available, but these studies have not been harnessed at all for theory building purposes. These prescriptions are so voluminous that it becomes tedious and error prone if a human being is to process the information to synthesise the building blocks of LSS. In keeping with the *bounded rationality* concept advanced by the Nobel laurate Herbert A. Simon, when confronted with voluminous information, humans take satisficing decisions (i.e., sub-optimal decisions) rather than optimal decisions (Simon, 1990). As a solution to avoid problems resulting from manual processing of voluminous information, the researcher developed a Deep Learning (DL) algorithm with Natural Language Processing (NLP) — a leading technique in supervised Machine Learning (ML) — to allow a machine (computer) to learn without explicit programming to allow patterns to emerge (Sharp et al., 2018). These patterns were then combined with the existing theorisations of Lean, SS and LSS to provide a theoretical model that has incorporated the essence of vast amounts of research that would otherwise have been wasted in theory building. To the best of the researcher's knowledge, no scientist at least in the social science realm has used ML in this kind of methodological triangulation.

## 1.6 Methods Overview

A variety of methods were used to answer the research questions to achieve research objectives. The theoretical model was built based on extant literature. As discussed already, this synthesis involved reviewing existing models of Lean, SS, and LSS, as well as ML to extract the theoretical essence of large volumes of literature prescribing a variety of CSFs for LSS implementation success. This model was then scoped in the industry to better understand the context of LSS application and to develop more relevant operational definitions for the theoretical constructs using extant literature as the starting point. These operationalisations helped the researcher to develop a questionnaire covering the manifestations of the theoretical constructs to deploy the questionnaire across a global sample of firms/practitioners that have implemented LSS projects to achieve product and service results. The data collected from these firms/practitioners (usable N = 296) were then analysed using partial least squares based structural equation modelling to test the hypotheses that constituted the theoretical model. The hypothesised test results, as well as the hypotheses themselves, were then interpreted both from a practical standpoint and a theoretical standpoint to highlight the findings of the study, including new knowledge claims. The methods followed by the researcher falls into a particular mixed method research design known as exploratory sequential design (Creswell & Clark, 2018), where the qualitative phase of the study (industrial scoping/industry engagement) informed the quantitative phase of the study (hypothesis testing) to arrive at the findings.

## 1.7 Structure of the Thesis

As Figure 1.3 depicts, the research unfolds in a methodical manner to provide a narrative; each chapter contributes to the overall picture. Chapter 2 reviews extant literature including prevailing theories and studies pertinent to the topic to identify the knowledge gaps, which lays the groundwork for Chapter 3.

Chapter 3 lays out the development of the conceptual model, revealing the theoretical foundation of LSS — more specially LSS implementation leading to success; thus chapter 3 uncovers the theoretical concepts, the relationships between the concepts in the form of eleven propositions and their boundary conditions.

Chapter 4 provides the details of the research methodology. Consequently, this chapter outlines the researcher's philosophy and how the researcher went about designing her research covering the stages involved (e.g., the qualitative phase followed by the quantitative phase), what qualitative data and quantitative data were collected and how, and the techniques/methods being used to analyse the data and explaining why these techniques/methods were chosen in favour of other available techniques/methods.

Chapter 5 covers the qualitative phase of the research (case study results based on qualitative data collected from 16 LSS practitioners) pertaining to understanding the context of LSS.

Chapter 6 refines the conceptual model developed in Chapter 3 to transform it into a testable theoretical model. Consequently, concepts became constructs (by being able to operationalise the concepts using case study data and the extant literature) and propositions became hypotheses through the necessary adaptations. The operationalisations of the concepts also paved the way to designing the survey instrument, which enabled quantitative data collection through statements on different facets of each concept (constructs) for which, agreement was sought from the respondents using a seven-point Likert scale.

Chapter 7 provides some relevant descriptive statistics but more importantly it provides the hypothesis test results outlining the strengths of the hypothesised theoretical relationships and discussing what these results mean from a practical standpoint as well as a theoretical standpoint.

Chapter 8 concludes the study based on the findings covered in the previous chapters and how these findings fulfilled the research objectives. The chapter also summarises the theoretical and practical contributions explaining how it contributed to new knowledge. Finally, the chapter discusses the limitations of the study and provides suggestions for further research.

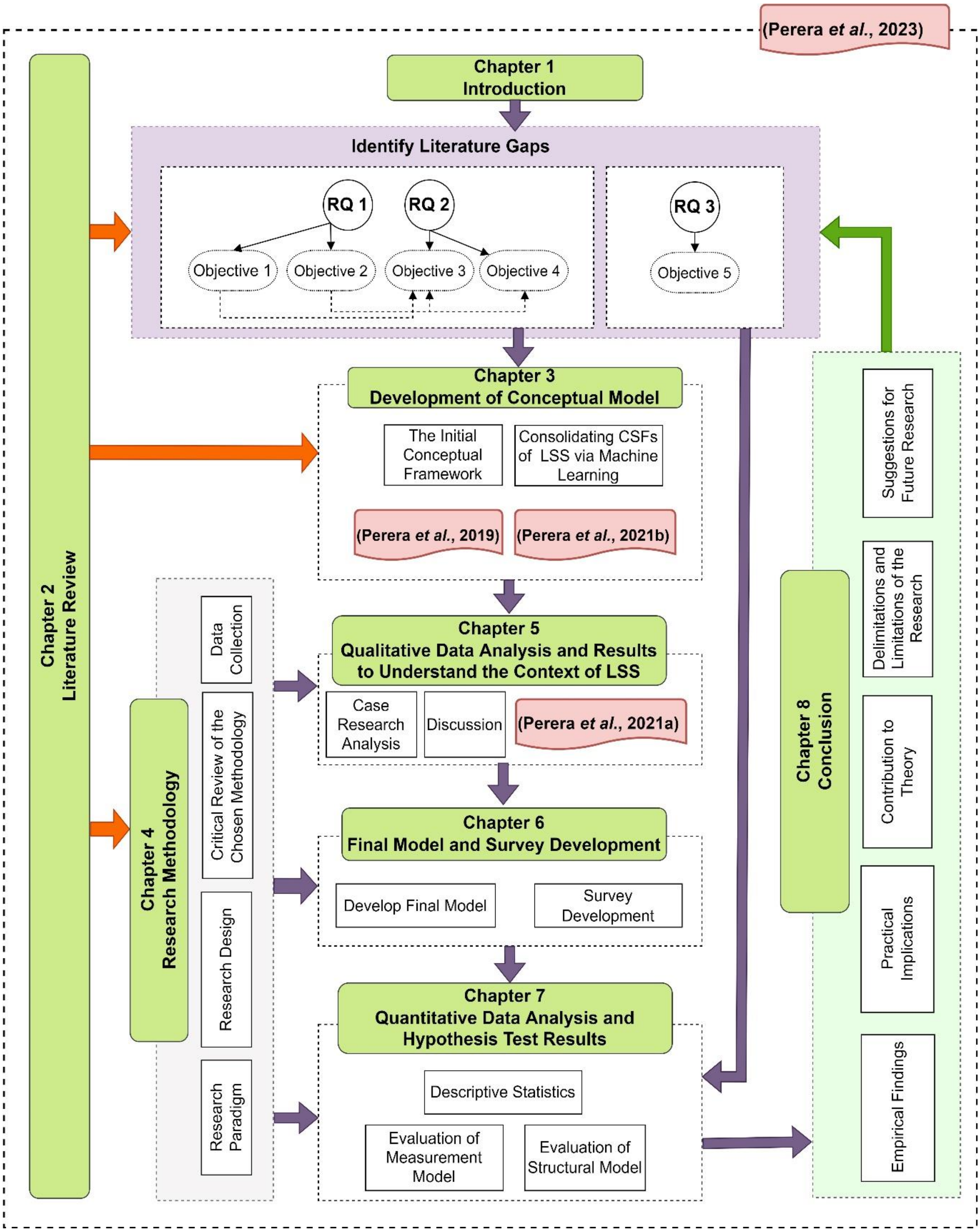


**Figure 1.3 Structure of the report**

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

Within the realm of organisational management, LSS has emerged as a transformative approach that promises enhanced operational efficiency and quality (Assarlind et al., 2013; Snee & Hoerl, 2007). Despite the prevalence of LSS as an improvement approach among practitioners and academia, there is no consensus on a universal definition of LSS, which serves as a constraint on the understanding of the theoretical underpinnings of LSS (Ahmed et al., 2022; Alblooshi et al., 2022; Antony et al., 2003b; Arnheiter & Maleyeff, 2005; Assarlind et al., 2013; Pepper & Spedding, 2010). This is not a surprise because as with its predecessors or co-existing allies, — most notably TQM, theory of constraints, Lean, and SS — LSS is a practitioner-focused discipline on the CI of processes and outcomes of a business (Muraliraj et al., 2018; Sanchez & Blanco, 2014). To gain a deeper understanding of TQM's definition and theoretical underpinnings, the Academy of Management Review dedicated a special issue in 1994 when TQM was at the height of its academic interest (Dean & Bowen, 1994). Similarly, this study attempts to gain a better understanding of the problem, albeit in a more modest scale. In this chapter, the researcher dissects the multifaceted dimensions of LSS under three broad thematic categories: the evolution of LSS, the current body of theory on LSS, and identifying the knowledge gaps on the theoretical underpinnings of LSS within the boundaries of the study (Figure 2.1). The most logical starting point of the literature review on the theoretical underpinnings of LSS is to review of the evolution of LSS.

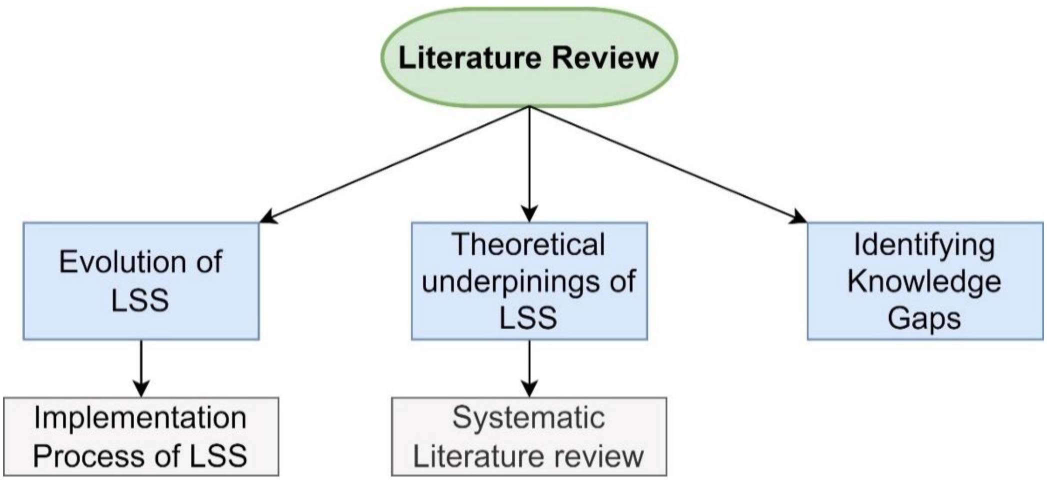


**Figure 2.1: Literature reviews focus**

## 2.2 Evolution of LSS

A good starting point for reviewing of the evolution of LSS is to examine the genesis of Lean and Six sigma, which can be viewed as constituent elements of LSS by a practitioner. However, it would be difficult to review the evolution of Lean and SS without very briefly defining TQM. TQM is a management philosophy/approach that emerged in the 1980s replacing then existent quality management approaches which focused on quality department-led quality control or quality assurance (Sousa & Voss, 2002; Summers, 2010). TQM as a philosophy is founded upon mutually interlocking principles (e.g., customer focus, viewing the organisation as a system, total employee involvement, CI, and decision making based on facts) that are supported by practices, tools, and techniques (Dean & Bowen, 1994; Hackman and Wageman, 1995; Sousa & Voss, 2002). TQM is regarded as an overlapping area of Lean (Dahlgaard & Mi Dahlgaard-Park, 2006; Shah & Ward 2003). Principles, practices, tools, and techniques espoused in TQM stem from the teachings of quality advocates such as Deming, Juran, Ishikawa and others (Hackman & Wageman, 1995; Summers, 2010).

### 2.2.1 The Genesis of Lean

The roots of Lean, centred on production efficiency, trace back to the 1920s with Henry Ford's innovative approach to mass production and the development of a moving production line laid the foundational concept of production efficiency, the essence of Lean (Alizon et al., 2008; Shook, 2007). Lean in its current form emerged when scholars attempted to decipher the operations management success of the production system of the Toyota Motor Corporation (TMC) — widely known as the TPS— and those of other Japanese manufacturing industries since the post-World War II recession (Holweg, 2007; Jayamaha et al., 2014; Shah & Ward, 2007). The term “Lean” was coined in 1988 by John Krafcik, a graduate student of James P. Womack at the Massachusetts Institute of Technology (MIT); Krafcik had worked at Toyota previously (Holweg, 2007; Shah & Ward, 2007). Consequently, “Lean” in its current form represents a culmination of Ford's pioneering efforts in mass production, along with Toyota's Production System, a concept defined and named by Krafcik that bridges historical manufacturing practices with contemporary academic research.

During 1950s -1960s, Taiichi Ohno and few other leading engineers in the TMC redeveloped and perfected the TPS based on Henry Ford’s production system and American supermarkets’ just in time (JIT)/pull production inventory management system (Womack & Jones, 1996). Ohno defines the TPS as an absolute elimination of wastes and an effort to make production flow continuously with minimum disruptions (Ohno, 1988). However, the best seller "The machine that changed the world", a book authored by Womack et al. (1990) was instrumental in revealing TMC's secret behind quality, reliability and customer satisfaction. The book can also be regarded as the initial attempts to unearth the theoretical underpinnings of the TPS/Lean. According to Womack& Jones (1996) Lean thinking comprises five key sequential principles (or concepts at theoretical level). These are as follows:

i. Define value: Specify value from a customers' standpoint (i.e., identify what the customer wants and is willing to pay for in fulfilling these wants).
ii. Value Stream Mapping: Identify the steps/process that constitute value (i.e., map the value stream to identify activities that add and do not add value to eliminate or minimise nonvalue adding activities).
iii. Creating Flow: Make the process flow smoothly without interruptions and hold-ups.
iv. Establishing Pull: This means pull production (manufacture is based on the customer demand), as opposed to push production (produce more and store, just in case) to avoid inventories/buffer.
v. Pursue perfection: This means continuous improvement, meaning improvement is a never-ending journey.

In Lean, waste is identified as any element that increases costs without adding value to the customer, a concept central to Lean thinking (Ben Ruben et al., 2017; Rawabdeh, 2005; Thomas & Barton, 2011; Vinodh et al., 2012). Though Lean is defined variously in literature, all interpretations converge on the principle of eliminating waste to enhance production efficiency and benefit the customer (Campos, 2013; Corbett, 2011; Gupta et al., 2016; Powell & Skjelstad, 2012; Womack & Jones, 1996). Liker (2004, p.35) elaborates on this through the 14 Principles of "The Toyota Way," which distil the essence of the TPS. Liker acknowledges the five principles that were introduced by Womack and Jones (2003), but he strongly believes that the culture behind TPS is a key factor in Toyota's success. Also, literature highlights that Lean is not only a set of systematic tools or practices which are focused on reducing wastes, but also a mind-set that needs to be cultivated within an organisation (Aij & Teunissen, 2017; McLean et al., 2015; Zugelder, 2012).

### 2.2.2 The Genesis of SS

Bill Smith, a reliability engineer at Motorola in 1987 developed the SS methodology as an effort to solve the most chronic problem in the company, which was failing to meet customer expectations in a cost-effective manner (Cheng & Chang, 2012; Muir, 2006; Pepper & Spedding,2010; Sin et al., 2015). After winning the 1988 Malcolm Baldrige National Quality Award, Motorola revealed its secret of rapid success to the world (Drohomeretski et al., 2013; Schroeder et al., 2008). Subsequently US manufacturing giants such as General Electric (GE), AlliedSignal and others adopted the SS methodology in the early 90's (Sin et al., 2015). Despite the fact that Motorola invented SS, it was GE's four-phase problem solving approach (measurement, analysis, improvement and control) that later became popular across the industry as the five-step structured problem approach: Define-Measure-Analyse-Improve-Control (DMAIC) (Salah et al., 2010). According to Chen& Lyu (2010) and Antony et al. (2017b) SS has enabled businesses to improve customer satisfaction while reducing costs through a reduction in variation, a reduction in defects, and an increase in productivity. Furthermore, through review of the two decades of extant literature, Sin et al. (2015) created a catalogue of evidence on SS implementation gains (economic benefits).

SS is also recognised in literature as a superior process capability metric, representing an advanced level of process performance (Antony, 2011; Huq, 2006; Laureani & Antony, 2019). Here in SS, the term mathematically refers to 6 times the standard deviation (σ) of a quality characteristic, symbolising excellent process capability under optimal conditions (i.e., when the process is well centred meaning process average = target value) with process average being six standard deviations (6*σ) away from the specification limits. However, SS literature assumes that under less ideal conditions, the process average may drift by 1.5σ towards a specification limit, leading to a Process Capability Index (Cpk) of 1.5 (2.0 in the best-case scenario) (Montgomery & Woodall, 2008). Even under this worst-case condition, the process would still have an impressive capability of meeting the specification resulting in only 3.4 defects per million opportunities (DPMO) (Antony et al., 2003; Arumugam et al., 2016). Therefore, a process meeting SS criterion is expected to achieve a $2.0 \geq Cpk \geq 1.5$, correlating to fewer than 3.4 DPMO, illustrating the high standard of quality and efficiency that SS aims to achieve.

As a quality improvement strategy, SS aims at achieving high-quality in a cost-effective manner (high return on investment). However, SS is invariably associated with the five-stage DMAIC problem solving sequence (Figure 2.2 presents key activities during each of the five stages) (Padhy, 2017; Price et al., 2018; Sin et al., 2015). This structured approach guides practitioners through the stages of problem identification, data collection, root cause analysis, solution implementation, and ongoing process control. The DMAIC framework ensures a systematic and evidence-based strategy for process enhancement, with a sharp focus on understanding customer requirements and aligning processes accordingly. According to Schroeder et al. (2008), SS as quality improvement strategy reduces variation in processes by using improvement specialists, structured methods, and performance metrics. However, there has been limited progress for empirical support for this proposition (more about SS theorisations later, under section 2.4.1).

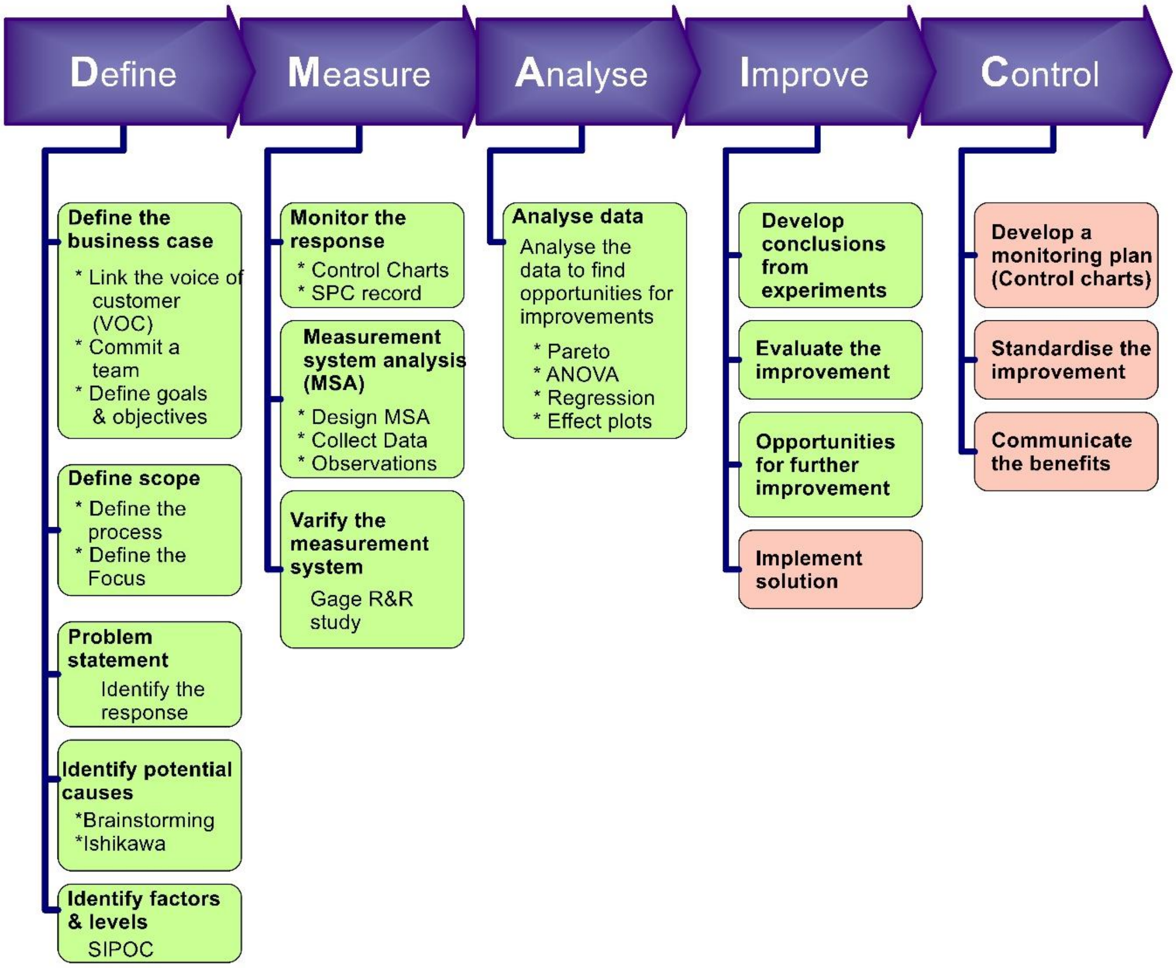


**Figure 2.2: DMAIC process (adapted from: Padhy, 2017; Price et al., 2018; Sin et al., 2015)**

### 2.2.3 Lean-SS Integration

SS and Lean are among the most significant methodologies used in the industry for process improvement (Salah et al., 2010). According to the literature, Lean and SS were initially integrated at the George Group LLC in 1986; George group is a management consultancy firm specialising in Lean and SS based in the US (Al-Aomar & Setijono, 2012; Salah et al., 2010). However, the demonstrated success of co-application of Lean and SS in the manufacturing industry led to their merger under the term "Lean six sigma" (LSS) or "Lean Sigma" around the year 2000 (Antony et al., 2012; Pepper & Spedding, 2010; Raval et al., 2018a)

The focus of the new synergy (i.e., LSS) was to overcome the limitations of both Lean and SS when practiced in isolation (Pepper & Spedding, 2010). Thus, a Lean approach offers solutions to waste in a variety of production environments and SS responses to the variation of the processes (Antony et al., 2003a; Rathilall & Singh, 2018). Therefore, the proponents of LSS argue that the use of two philosophies within a single improvement project reduces both process variation and lead time and other value-adding outcomes of Lean to achieve a higher level of customer satisfaction, which neither of these two philosophies could achieve alone (Albliwi et al., 2014; Antony et al., 2003a; Arnheiter & Maleyeff, 2005). Hines et al. (2004) consider SS to be a good complement to Lean as SS addresses variation in a manner compatible with the lean strategy. However, they employ SS as just another (but important) Lean tool. This undermines the strength of the DMAIC strategy of problem-solving. Similarly, it is documented that some companies practice Lean and SS separately following one method after the other depending on the complexity of the project (Lande et al., 2016).

The emergence of LSS in the advent of the 21$^{st}$ century through manufacturing strategies (e.g., TPS/Lean manufacturing) and quality philosophies (e.g. statistical quality control, Deming's 14 points, Plan-Do-Check/Study-Act iterative cycle of continuous improvement) in the 20$^{th}$ century have been discussed by several authors including Salah& Rahim (2019), Ruben et al. (2018b), Corbett (2011), Andersson et al. (2006), Mangelsdorf (1999), Maleyeff et al. (2012), Pepper& Spedding (2010), and McCarthy& McCarthy (2008). Figure 2.3 depicts this evolution in detail.

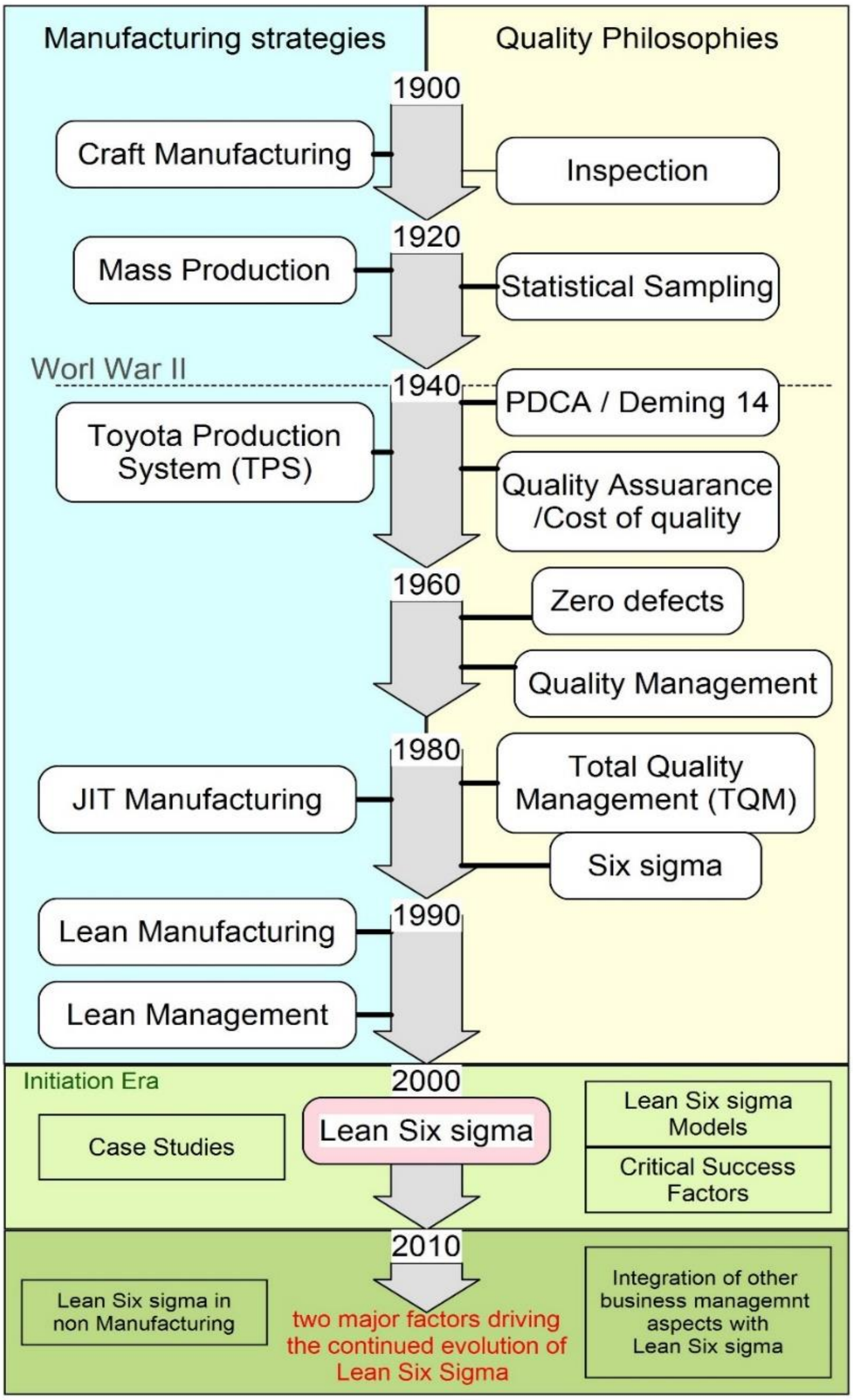


**Figure 2.3: Evolution of LSS (Adapted from several pieces of literature)**

Some authors (e.g., Alsmadi & Khan (2010) and Arcidiacono et al. (2016)) have explained descriptively (e.g., using charts and diagrams) how Lean and SS can be implemented and sustained. However, some propose that SS can be used first to improve the effectiveness of the processes and Lean can be applied thereafter to improve the efficiency of the system, whereas others believe that Lean tools and practices can be embedded into SS methodology in the problem-solving phase (Burneo-Celi & Temblador-Perez, 2018; Sreedharan & Sunder, 2018). However, to accomplish the goal of integration Salah & Rahim (2019) argue that it is better to draw on both methodologies at the same time. Their argument is that this approach provides a more comprehensive and effective approach since it leverages the strengths of each methodology concurrently, leveraging their individual strengths and capabilities. Arnheiter& Maleyeff (2005) consider LSS as an approach that strikes the right balance between the customer perspective and manufacturer perspective. They argue that an LSS organisation must leverage on the strengths of both Lean and SS. Figure 2.4 represents their argument graphically to demonstrate that adopting both approaches results in a balanced approach.

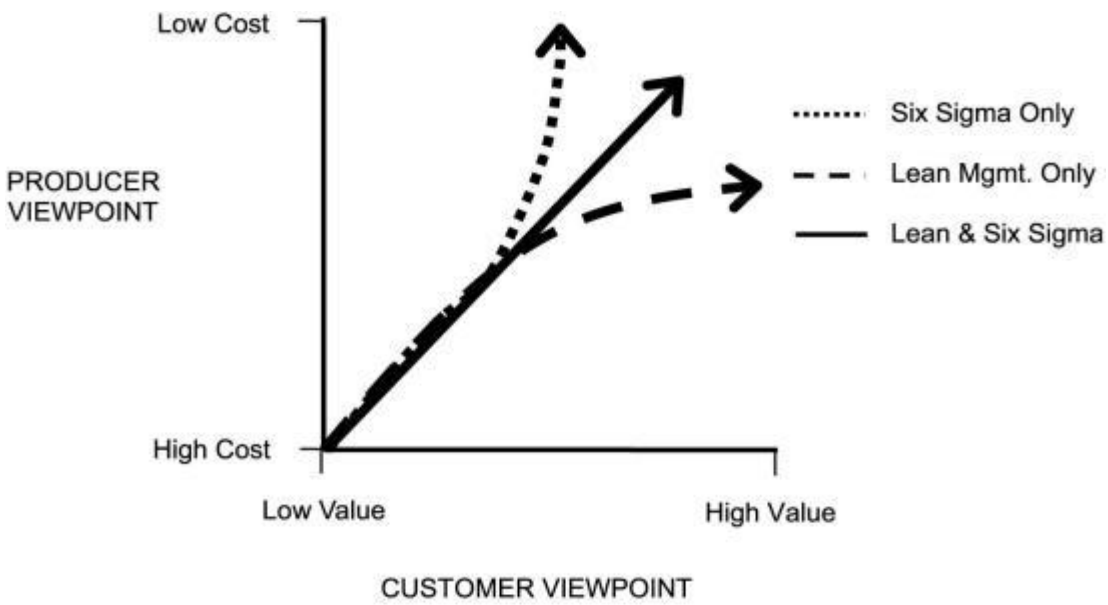


**Figure 2.4: Competitive advantage of LSS organisation (Source: Arnheiter& Maleyeff, 2005)**

Antony et al. (2003b) attempted to show the fundamental differences between Lean production and SS by showing specific goals each approach aims to achieve in order to solve a wide variety of problems associated with products and processes (see Table 2.1).

**Table 2.1 The fundamental differences between Six Sigma and Lean Production methodologies (Source: Antony et al., 2003)**

| Focus or goal | Six Sigma | Lean Production |
|---|---|---|
| Customer value stream | No | Yes |
| Creating a visual workplace | No | Yes |
| Standard work sheets | No | Yes |
| Optimising work-in progress inventory | No | Yes |
| Good house keeping | No | Yes |
| Process control and monitoring | Yes | No |
| Reducing variation and achieve uniform process outputs | Yes | No |
| Application of statistical tools and techniques of varying degrees of sophistication | Yes | No |
| Applying a structured, rigorous, and well-planned problem-solving methodology | Yes | No |
| Reducing waste due to waiting, over processing, motion, over production, etc. | No | Yes |

Similarly, numerous authors (e.g., Arnheiter & Maleyeff, 2005; Mustapha et al., 2019; Papic et al., 2017) have attempted to demonstrate how Lean Manufacturing (LM) and SS complement each other as a structured approach to problem-solving. Antony et al. (2003a) as well as Chen et al. (2010) assert that LSS as a system has important characteristics for process improvement because Lean tools and techniques eliminate much of the waste in a process, while SS focuses on resolving chronic problems. Many publications in the literature suggest that LSS is applicable in the service industry (Antony et al., 2017a; Bhat et al., 2016; Chandrakumar et al., 2016; Cheng et al., 2012b). Whether LSS as a theoretical framework to nonmanufacturing as well as it is to manufacturing remains to be seen (more later in section 2.6.2).

In conclusion, LSS proponents argue that LSS is not merely the sum of Lean and SS methodologies, but an amalgamation and refinement of the two approaches to become a coherent whole (Ahmed et al., 2022; Pepper and Spedding, 2010). The key focus of LSS is to increase customer value by reducing variation, increasing effectiveness, and offering solutions to overcome the limitations of Lean and SS when used separately (Albliwi et al., 2017; Antony et al., 2003; Pepper and Spedding, 2010). As noted, some experts assert that Lean tools and methodologies can be incorporated into SS methodology (DMAIC) to solve problems, while others assert that processes should be improved through SS first before using Lean practices and tools (Mustapha et al., 2019; Sreedharan et al., 2018). However, the best mechanism of combining Lean and SS to present a universal model on LSS has not been critically argued and presented in empirically testable form in the literature (Muraliraj et al., 2020; Salah and Rahim, 2019).

## 2.3 Implementation Process of LSS

It is argued in the literature that the DMAIC framework, adapted from SS, serves as the structured roadmap for LSS projects as well. The argument is that as part of LSS's DMAIC toolkit, practitioners have access to all SS and Lean tools necessary to effectively address complex issues (Mustapha et al., 2019; Price et al., 2018). Salah & Rahim (2019) argue that as is the case in SS, which is guided by the five-step DMAIC process, Lean too has a specific implementation road map guided through the five key steps of Womack and Jones (1996). Thomas et al. (2016) attempted to accommodate DMAIC within Womack and Jones' five steps of Lean to imply that DMAIC operates within Lean, although the authors have not provided a theoretical basis for their model (Figure 2.5). One possibility for their thinking could be that the customer value proposition is embedded in Lean (hence Womack and Jones' five steps of Lean) and it should therefore appear in the outer circle.

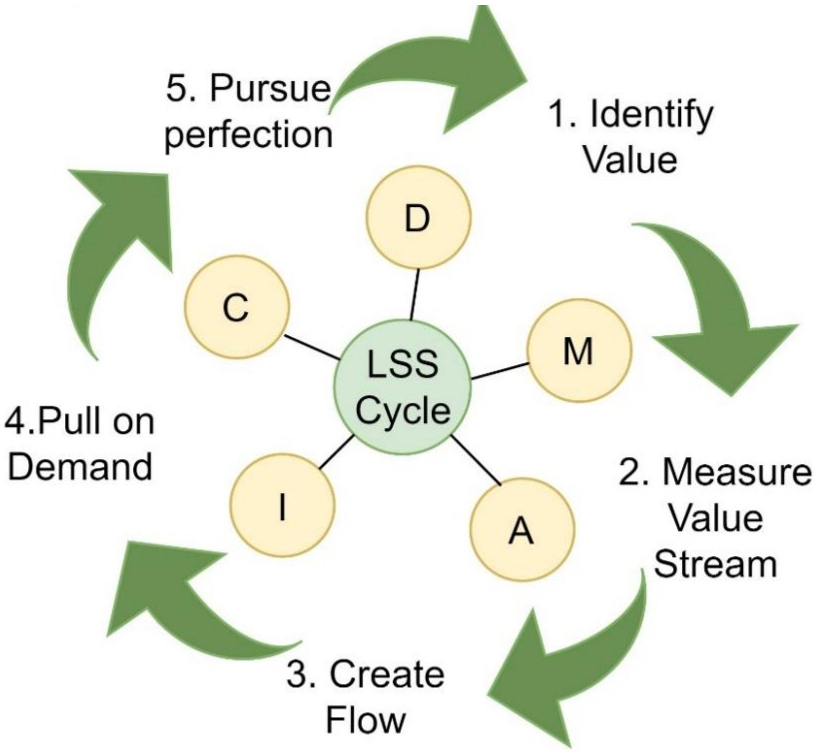


**Figure 2.5: LSS cycle adopted from literature (Source: Thomas et al., 2016)**

Over the past two decades, LSS has been implemented worldwide in a variety of processes distributed in the manufacturing to service (nonmanufacturing) sectors, such as healthcare, financial services, higher education (Martins Rosa & Broday, 2018). Although LSS success stories have been promoted strongly, quite a few LSS projects are reported to have failed, leading to a new stream of literature on so-called LSS failure (or inhibiting) factors (Abu Bakar et al., 2015; Fadly Habidin & Mohd Yusof., 2013; Gupta et al., 2019). Learnings from successful LSS applications as well as successful LSS applications have resulted in a rich stream of literature on critical success factors (CSFs) of LSS; this aspect is covered as a separate theme in the next chapter.

## 2.4 The Theoretical Underpinnings of LSS

Unlike Lean, and to some extent SS (covered in section 2.4.2), LSS has not yet been subjected to the same level of scrutiny (Bajjou & Chafi, 2019; Lameijer et al., 2019; Pepper & Spedding, 2010; Shah & Ward, 2003) as they have. This could be due to changes in the research landscape or the intertwined nature of SS/LSS within an organisation's overall quality system (Antony et al., 2018). To overcome this issue, some researchers have considered LSS as a project-by-project management approach rather than a management theory on quality and operational performance (Linderman et al., 2003; Schroeder et al., 2008; Zu et al., 2008b). A critical factor in supporting this project focus is that by design, SS is a project-based methodology (Schroeder et al., 2008), and that LM can be integrated with DMAIC. However, the absence of a theoretical basis for this approach can lead to dismissing LSS as a fad, although the practice of LSS may not lose its value as long as results keep coming (George, 2019).

This section describes the process of identifying, selecting, and evaluating relevant conceptual models related to SS and LSS. It is important to note that in this section (and even elsewhere in this chapter), the term “model” is used to mean a model that contains theoretical concepts of the phenomenon—Lean, SS, LSS—as explanatory constructs (predictors) and performance or some other aspect of the organisation (e.g., dynamic capability) as the explained construct (response).

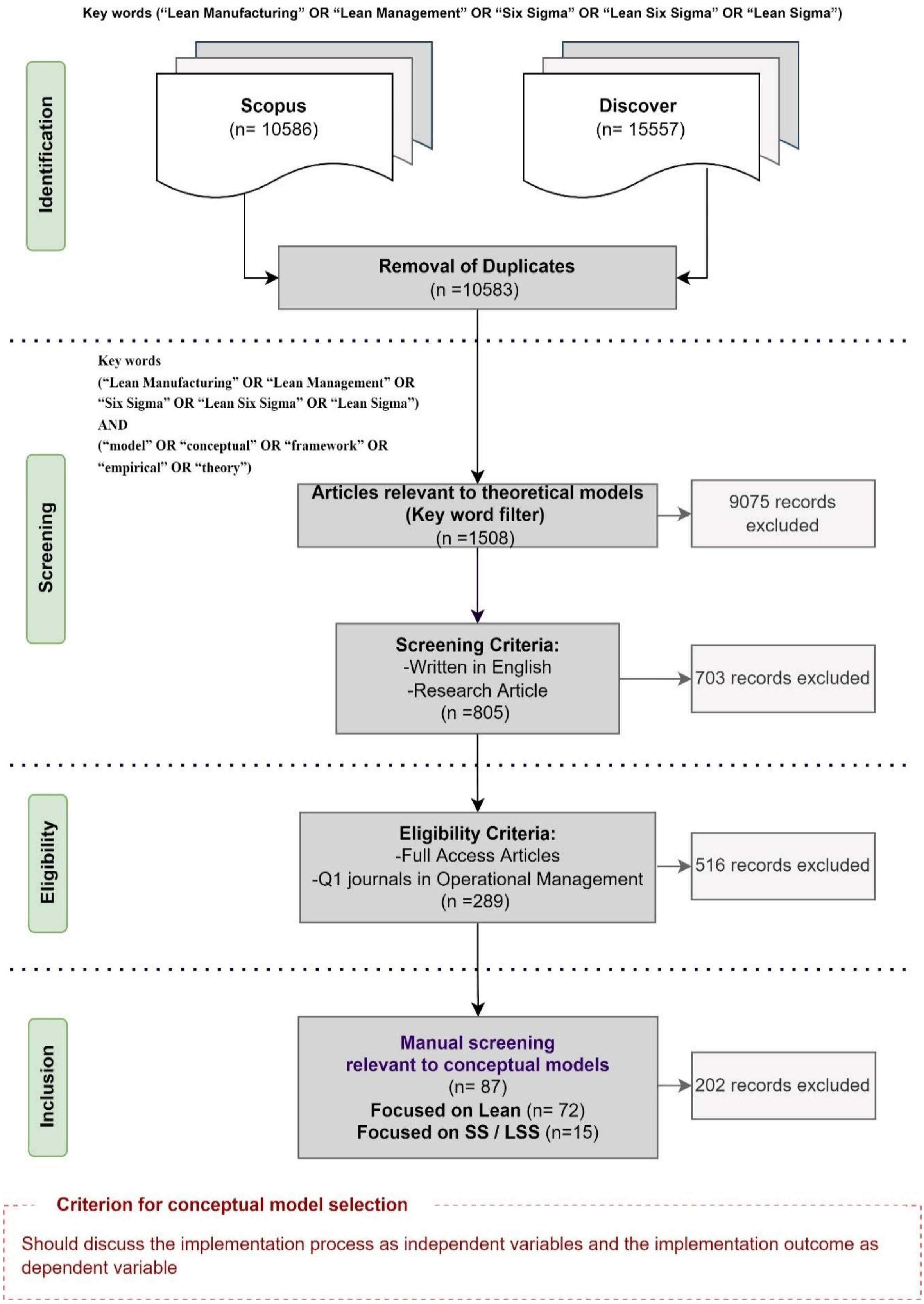


**Figure 2.6: PRISMA flow for the systematic literature review**

The article search process on models was initiated by conducting a systematic review. Firstly, a comprehensive literature search was conducted using SCOPUS and Discover by EBSCO to gather the most relevant articles published up to 30 November 2023 covering a diverse range of topics under Lean, SS, and LSS. Following the incorporation of specific keywords (Figure 2.6) which have the highest likelihood of returning Lean, SS and LSS models, 1,498 articles were extracted. Further refinement included filtering for English journal articles, yielding 709 articles. Following the eligibility criterion "Q1 journals only", only 289 conceptual models were retained. Five major models of Lean and 15 SS and LSS theoretical models were selected by using the essential requirement of having performance as the explained variable and organisational behaviour as an explanatory variable. Figure 2.6 depicts the article screening process in a PRISMA (Preferred Reporting Items of Systematic reviews and Meta-Analyses) flow diagram[2]. Thus, Table 2.2 summarises the selected Lean, SS, and LSS models and their approaches or theoretical lenses.

**Table 2.2 The selected Lean, SS and LSS models**

| Model | Literature | Approach/Theoretical Lense (where it is reasonably explicit) | Research Category |
|---|---|---|---|
| Lean | Sugimori et al. (1977) | Respect for people as essential elements of TPS and Lean | Conceptual |
| Lean | Shah & Ward (2003) | Emphasis on four interrelated Lean manufacturing practices (JIT, TPM, TQM, and HRM) | Empirical |
| Lean | Shah & Ward (2003) | Represents the conceptual domain of Lean production | Empirical |
| Lean | Jayaram et al. (2010) | Focus on micro aspects of TPS/Lean and their impact on manufacturing performance. | Empirical |
| Lean | Shook (2010) | Explore cultural change in organisations towards achieving superior manufacturing performance | Conceptual |
| SS | Linderman et al. (2003) | Goal theoretic approach to explain SS Performance (a concept paper) | Conceptual |
| SS | Linderman et al. (2006) | Goal theoretic approach to explain the role of goals in improvement teams | Empirical |
| SS | Arumugam et al. (2016) | Influence of challenging goals and structured methods on SS project performance | Empirical |
| SS | Schroeder et al. (2008) | Emphasises on leadership support, process management, and employee involvement in SS project success. | Conceptual |
| SS | Krueger et al. (2014) | Emphasises on strategic alignment, leadership engagement, employee engagement and empowerment in all levels of the organisation in SS project success. | Conceptual |
| SS | Zu et al. (2008b) | Emphasises on the critical role that leadership, culture, and project management play in SS project success. | Empirical |

[2] Source: http://prisma-statement.org/prismastatement/flowdiagram.aspx?AspxAutoDetectCookieSupport=1

| Model | Literature | Approach/Theoretical Lense (where it is reasonably explicit) | Research Category |
|---|---|---|---|
| SS | Sin et al. (2015b) | Focus on knowledge creation in SS project performance, based on knowledge-based view. | Empirical |
| SS | Anand et al. (2010) | Contribution of explicit and tacit knowledge contribute to SS project success. | Empirical |
| LSS | Ahmed et al. (2022) | LSS Practices directly and indirectly leading to Quality Improvement | Empirical |
| LSS | Sim et al. (2021) | Effect of LSS practices (predictors) on quality performance (response); a research paper | Empirical |
| LSS | Muraliraj et al. (2020) | Exploring how Lean and Six Sigma's distinctive practices relate to potential absorptive capacity (PACAP) and realised absorptive capacity (RACAP), based on dynamic capability. | Empirical |
| LSS | Raval et al. (2018a) | Framework to LSS implementation via enablers | Empirical |
| LSS | Sreedharan& Sunder (2018) | A four-phased LSS framework, for practical implications (a case study). | Empirical |
| LSS | Thomas et al. (2008) | An integrated LSS framework for manufacturing industry (a case study). | Empirical |

### 2.4.1 Lean Models

Some major theoretical contributions to the field of Lean manufacturing are summarised in

Table 2.3. The synthesis of these five pieces of literature follows:

**Table 2.3: Description of five main studies on Lean**

| Citation | Methods/Findings/Contribution |
|---|---|
| Sugimori et al. (1977) | In this conceptual paper published in the International Journal of Production Research, the authors use their own experience associated with the TPS to unearth the two core concepts that underpin the TPS: just-in-time (JIT) production and respect for people. JIT production enabled the TPS to adjust the production schedules to account for variations in the demand side manufacturing processes themselves to minimise inventory unbalances, idling workforce, machinery, and equipment. Hence JIT can be viewed as the prime mover of Lean aimed at reducing nonvalue adding activities and workforce. Toyota culture of respect for people enabled Toyota to harness the full capability of its people through engaged participation to improve the productivity of their workstations. |
| Shah & Ward (2003) | In this research paper published in the Journal of Operations management (JOM), via the extant literature, the authors identified 22 Lean manufacturing practices intricately bundled into four interrelated practices — JIT production, total preventive maintenance (TPM), TQM, and human resource management (HRM) — which were treated as constructs reflecting the 22 practices. |

| Citation | Methods/Findings/Contribution |
|---|---|
| | Through data collected from 1748 manufacturers the authors used exploratory factor analysis (EFA) — principal components analysis followed by Varimax orthogonal factor rotation method — to demonstrate the validity of the four practice bundles. The interrelatedness between the bundles was demonstrated by the cross-loading pattern returned in the rotated components matrix. |
| Shah & Ward (2007) | In this research paper published in the JOM, through the extant literature, the authors identified 41 measures of Lean production that reflect ten constructs — supplier feedback, JIT delivery by the suppliers, supplier development, customer involvement, pull production, continuous flow, setup time reduction, TPM, statistical process control (SPC), and employee involvement — which according to the authors, represent the conceptual domain of Lean production in its entirely. The validity of the constructs was empirically established via a two-stage data analytic process involving a training sample of 63 cases to conduct EFA and a cross-validation sample of 280 cases to conduct confirmatory factor analysis (CFA). |
| Jayaram et al. (2010) | In this research paper published in the International Journal of Production Economics, the authors concatenated micro aspects of TPS/Lean manufacturing into two components: TPS practices and TPS rules to hypothesise that Lean manufacturing performance in terms of cycle time reduction, quality performance, cost reduction performance, and delivery speed performance (hence four dependent variables) is explained and predicted by the said two constructs and their two-way interaction (i.e., TPS practices*TPS rules). The empirical analysis involving data collected from 322 cases (respondents) supported some of the main effects and two-way interactions to keep the authors' hypothesis in contention. A notable observation is that their four regression models did not fit to data very well (e.g., the adjusted $R^2$ of the model predicting delivery speed performance was only 12.6%). |
| Shook (2010) | In this research paper published in the MIT Sloan Management Review, the author (a former Toyota employee) uses his own experience and ethnographic observations to answer the question "how can managers change the culture of their organisation" to achieve the superior manufacturing performance that the TPS achieves? (Shook, 2010, p. 63). The author argues that changing the way people do things, adopting a new way of thinking, employee empowerment, and appreciating that the way in which the problems are solved reflects a superior culture that results in superior manufacturing performance. |

The theoretical underpinnings of Lean manufacturing seem to be contingent upon the lens through with each author(s) views Lean manufacturing. For example, Sugimori et al. (1977) used an assembly line lens to bring JIT into the limelight. Shah & Ward (2003) seems to have used a strategic management lens to bring practice bundles into the limelight. The term ‘bundle” (bundles are always difficult to untangle) in strategic management implies inimitability to provide superior competitive advantage to a firm (Barney & Arikan, 2005; Herrmann, 2005). In a different study, Shah & Ward (2007) seems to have used systems thinking as their lens to outline as many as 10 interconnected processes to represent Lean. Jayaram et al. (2010) also seem to have used system thinking as their lens, but they were focused on evolving a parsimonious theory on Lean/TPS. The fact that they represented TPS practices via a single construct demonstrates model parsimony very clearly. Finally, Shook (2010) seems to have used an industrial anthropologist’s lens to bring culture change as the catalyst for improving manufacturing performance. Of course, culture change for superior performance is nothing new to operations management. Edwards W Deming emphasised culture change in vivid ways through his textbooks (for three diffrent textbooks of Deming see Deming, 1982; Deming, 1986; Deming, 1994) and seminars.

Although not all authors listed in Table 2.2 have explicitly stated this (Shah and Ward do), continuous improvement happens to be the binding glue of Lean practices and approaches. Finally, the manufacturing emphasis by the authors pose a lack of generalisability of Lean manufacturing concepts across all production and nonmanufacturing settings. For example, JIT or pull production will not apply to primary industries due to perishability and seasonality of commodities while adaptations may need to be made to some Lean manufacturing concepts (depending on the level of abstraction) when being applied to services (e.g., TPM applies to machines but not all services use the kind of machines used in manufacturing). However, at a more abstract level, eliminating waste and nonvalue adding activities, respect for people, and CI become generalisable concepts across the nonmanufacturing sector. For example, Jayamaha et al. (2014) empirically tested the Toyota Way (TW) — Toyota’s core values and guiding principles of the TPS are founded upon respect for people and continuous improvement — in the sales, logistics, and marketing functions of Toyota’s international service networks. Through secondary data available on Toyota’s logistics, sales, and marketing workforce ($n$ = 2613) in 27 countries, they found strong support to their hypothesis that people development (reflected by respect for people and teamwork) leads to process improvement (reflected by kaizen[3], Genchi Genbutsu[4], and patience[5]) that results in superior performance.

From this point onwards the researcher will use the term Lean production as a more generalisable conceptualisation of Lean manufacturing (production can mean transforming inputs into of any tangible or intangible output) to cover a wide variety contexts and organisations. Similarly, the term Lean management (another generalisable term) or simply Lean have been used by the researcher to mean management of processes based on Lean principles. Depending on the context, the researcher uses the terms “Lean production”, “Lean management”, and “Lean” interchangeably in this thesis.

### 2.4.2 SS Models

The theoretical foundation of SS is anchored in the principles of statistical process control and process improvement; SS draws heavily from the contributions of quality advocates such as Walter Shewhart and W. Edwards Deming (Breyfogle, 2003; Schroeder et al., 2008; Snee & Hoerl, 2003). As mentioned earlier, central to SS is the DMAIC (Define, Measure, Analyse, Improve, Control) framework, which provides a systematic roadmap for identifying defects, reducing process variations, and enhancing overall quality (Montgomery et al., 2008; Pande et al., 2000). The theoretical essence of SS underscores data-driven decision-making, meticulous measurement, and statistical analysis to achieve process improvements that are both quantifiable and sustainable.

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[3] The Japanese word kaizen means changing for better to highlight continuous improvement.

[4] The Japanese phrase Genchi Genbutsu refers to a practice which require associates be where action takes place to identify the root cause(s) of a problem; Genchi Genbutsu is everyone’s responsibility (Jayamaha et al., 2014).

[5] The actual term used by Totota is Challenge; Challenge reflects patience, in the sense continuous improvement is incremental and long-term oriented (Jayamaha et al., 2014).

***Models that Used Goal Theory as the Primary Theory to Explain SS Phenomenon***

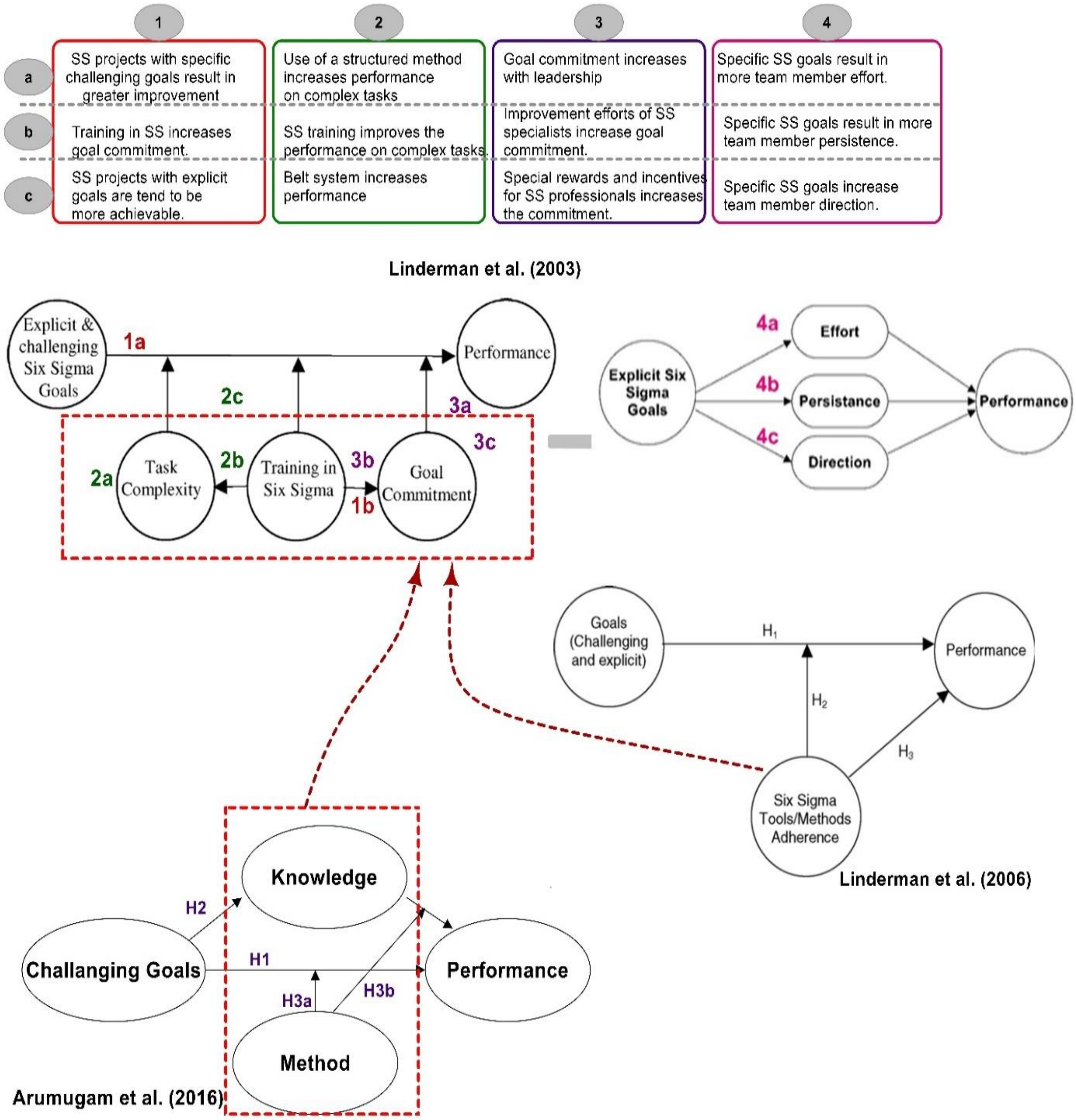


**Figure 2.7 Models incorporating goal theoretic perspective to explain SS (Adapted from: Linderman et al., 2003 and Linderman et al., 2006 and Arumugam et al. 2016)**

For the convenience of the reader, Figure 2.7 presents the three theories/models based on goal theory side-by-side. Both Linderman et al. (2003), Linderman et al. (2006) and Arumugam et al. (2016) have all incorporated goal theory as their theoretical lens to the understand SS as a performance improvement phenomenon. Both studies provide a unique perspective on the topic. Goal theory, which is sometimes called goal setting theory, is a theory on human motivation advanced by Edvin Locke in the late 1960s (See Locke, 1968). The theory posits that people are motivated to perform at work when clear, specific, and challenging goals (as opposed to unclear, mundane goals) have been set upon them. The theory also refers to task complexity (breaking down the task into subtasks to manage complexity) and goal commitment: the worker buy-in, which in turn depends on the importance and self-efficacy (one's confidence in their ability to carry out the actions required to achieve specific performance goals) (Covington, 2000; Locke & Latham, 2015).

Linderman et al. (2003) theorise that the goal orientation embodied in SS of 3.4 defects per million opportunities (DPMO), requires challenging goals. In keeping with the goal theory Linderman et al. posit that the goal → performance relationship is moderated by the complexity of the tasks undertaken, goal commitment, and training in SS. They also argue that both goal commitment and task complexity can be enhanced by training, which is depicted in Figure 2.7. Arumugam et al. (2016) explored the intricate causal relationships among challenging goal setting and performance using 'Knowledge' as a mediator and 'Method' as a moderator. Notably, both Linderman et al. (2003) and Linderman et al. (2006) incorporated goal theory but did not delve into behavioural aspects of quality improvement, such as leadership and culture. This was also the case for Arumugam et al. (2016). Apart from goal setting theory, Arumugam et al. (2016) used the knowledge management theory (learning and knowledge creation in teams) and sociotechnical systems (STS) theory to develop their model (Figure 2.7). STS theory is an important theory as it recognises that design and performance of an organisational system can only be understood and improved only if the social elements and technical elements are harmonised as interdependent elements (Trist, 1981). In Arumugam et al. (2016)'s model, STS theory is used to explain the authority vested in teams to alter work methods to enhance performance, which is congruent with the "structural exploration" aspect of SS found by Schroeder et al. (2008) in their action research.

The search for keywords produced no empirical studies that tested the model presented by Linderman et al (2003). However, the model posited by Linderman et al. (2006) has been empirically tested in the same publication using survey data collected from 188 SS projects (the units of analysis) where SS Tools/Methods Adherence (i.e., Goals* SS Tools/Methods Adherence) was used to represent the moderation hypothesis H2 (Figure 2.7). Linderman et al.

(2006) found support for all their hypotheses, but this researcher observes that their model returned a moderate coefficient of determination, even with the control variable (local vs foreign site) being included as an additional predictor ($R^2$ with the control variable only as the predictor of performance = 11%; $R^2$ with the theoretical predictors and the control variable as the protector of performance = 27.5%).

The model posited by Arumugam et al. (2016) has also been tested within the same study using a method similar to that used by Linderman et al. (2006), again using a SS project as the unit of analysis (sample size = 102 SS projects). The regression analysis test results found support for most of the hypotheses posited by Arumugam et al. (2016) (Figure 2.7). The researcher notes that the coefficient of determination (the $R^2$) of the model that Arumugam et al. (2016) tested (= 70.8%) is much higher than that corresponding to the model tested by Linderman et al. (2006) implying that Arumugam et al.'s model fits to data better than that of Linderman et al. (2006). This could partly be due to the two different theoretical perspectives. Unlike Linderman et al. (2006) who used only goal theory as the theoretical lens, Arumugam et al. used goal theory, knowledge management theory, and STS theory as their theoretical lenses resulting in more predictors and more theoretical alignment with SS.

Despite the contribution to LSS theoretical knowledge, all the SS models discussed above have four limitations: first, they are not sufficiently focused on behavioural aspects of quality improvement, such as leadership and culture. Secondly, none of these models explicitly consider project-related contingencies, which are pivotal for project success. Thirdly, although these models are SS-focused and provide valuable insights into specific aspects of SS and performance improvement, they do not provide a comprehensive overview of an LSS holistic implementation. Finally, Lean principles are noticeably absent from these models, even though Lean and SS can work in tandem as LSS. Thus, these models cannot be directly incorporated into LSS implementation.

*Models that Used Culture/Context to Explain SS Phenomenon*

Figure 2.8 presents the three theoretical models that use culture/context to explain the SS phenomenon. Similar coloured dashed ellipses indicate similar meanings for constructs across models.

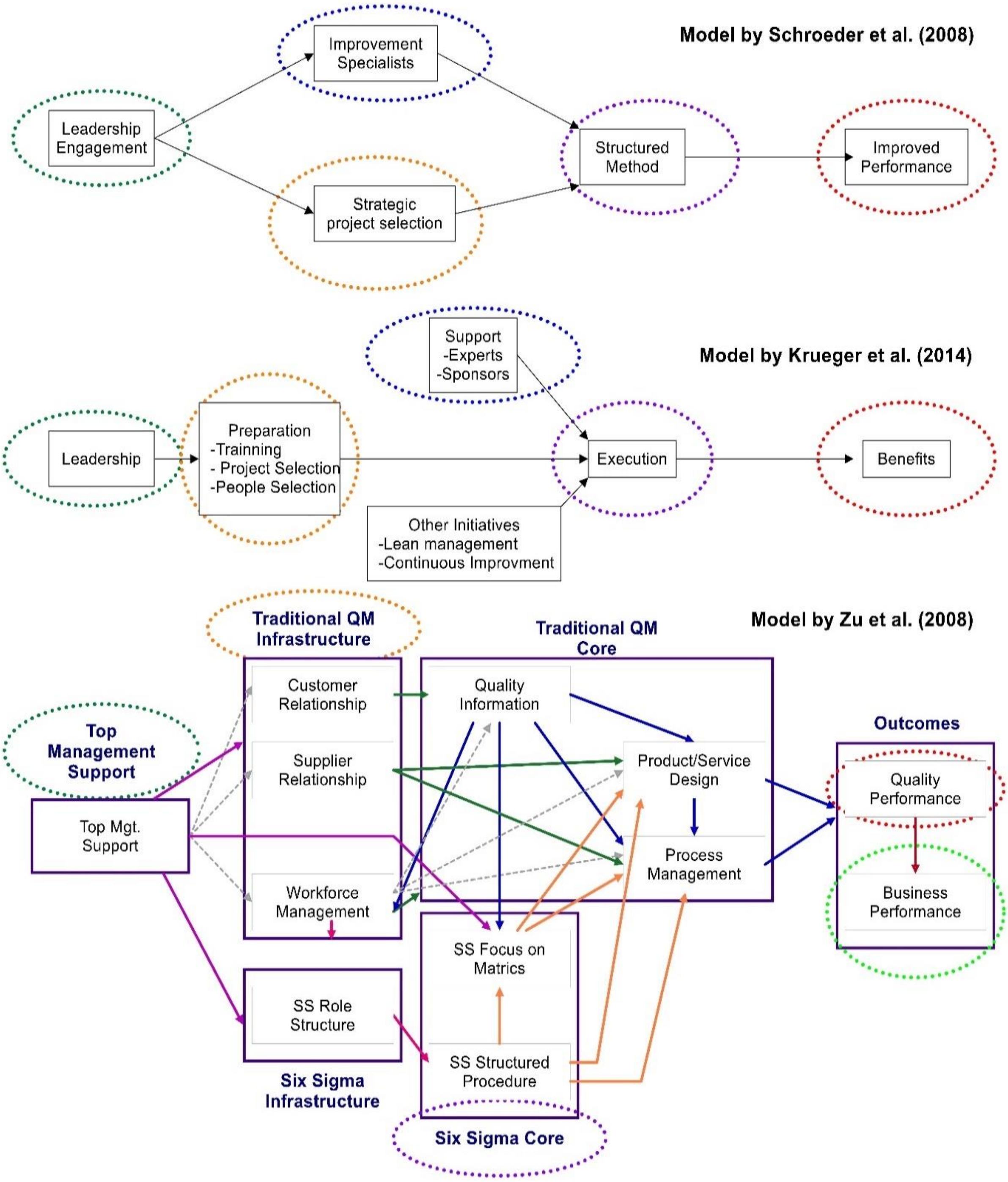


**Figure 2.8 Models incorporating culture/context to explain SS**

**(Adapted from: Krueger et al., 2014; Schroeder et al., 2008; Zu et al., 2008)**

Schroeder et al. (2008) addressed some of the shortcomings of the work of Linderman et al. (2003) and Linderman et al. (2006) by including organisational behaviour elements with less model complexity. They used grounded theory in their fieldwork (based on data collected from two SS companies with four projects in each), and the literature to evolve a more complete theory on SS. They use the phrase *"Parallel-meso structure"* to define the SS reporting structure that runs parallel to the organisational hierarchy. The prefix 'meso' signifies the relationship that integrates both macro (organisation) and micro (individuals and groups) levels of analysis resulting in positive and mutually reinforcing behaviour. Schroeder et al. (2008) seem to bring together both the practical/hard aspect of SS such as the SS vocabulary and the application of tools as well as the soft elements of quality improvement (e.g., strategic direction, skills development, and sociotechnical elements). They highlight that leadership skill is a vital characteristic in the selection of improvement specialists as well as selection of the right projects for improvement. Furthermore, they assert that a structured method (DMAIC) consists of using standard quality tools to measure performance via two matrices: customer focus and financial focus.

Finally, it must be noted that the median model posited by Schroeder et al. (2008) (the mediators being Improvement Specialists, Strategic project selection, and Structured Method) possesses many features of LSS based improvement. For example, LSS projects also need to be strategically selected by the leaders and improvement specialists (in many cases LSS black belts and green belts) are needed and need to be nurtured by the leaders, and almost always, a structured problem-solving method must be applied to improve performance. If the model posited by Schroeder et al. (2008) can be modified to cover SS and LSS both taking into account the current understanding of LSS, it could be quite possible that Lean makes its presence felt mostly in structured problem solving (the DMAIC process) because from a problem solving angle, driving out waste (Lean) and driving out variation (SS) are often overlapping areas. For example, excessive variation leads to wastes (nonconformities), customer dissatisfaction (e.g., compromised quality when a product is in use, tolerance and fit issues, excessive mechanical wear), and even can be a loss to society (if one is as philosophical as Genichi Taguchi) (Kackar, 1986; Wang et al., 2021).

The SS model posited by Krueger et al. (2014) is similar to that presented by Schroeder et al. (2008), particularly on the emphasis on strategic alignment and leadership engagement. Both models stress the necessity of integrating SS initiatives with an organisation's broader strategic objectives, understanding that isolated SS efforts are insufficient for long-term success. The importance of employee engagement and empowerment (two of the essential features of CI and the TPS/Lean) is uniquely emphasised by Krueger et al. (2014) compared to Schroeder et al. (2008). The authors argue that a successful implementation of SS requires both top-down leadership and a bottom-up approach that encourages employees at all levels to take part in improvement efforts. By emphasising a collaborative approach, this perspective recognises that SS's effectiveness depends on the active participation of everyone (something that TQM also emphasises) in the process.

Zu et al. (2008) also identified three new practices—SS role structure, the structured improvement procedure, and focus on metrics—as being critical for implementing SS to improve quality performance. Zu et al. (2008) posited the SS core and the traditional Quality Management (QM) core (i.e., TQM) as parallel acting mediators in the Top Management Support→ Quality Performance relationship, but the inclusion of both QM and SS constructs (the model contains 12 constructs) make the model complex from a phenomenon explanation standpoint (many constructs and hypotheses). The hypothesised model was based on existing literature and the model has been tested empirically ($n = 226$) in US manufacturing plants using structural equation modelling (SEM). Zu et al. (2008) found that their model was a good fit to data (RMSEA < 0.048). Not testing the model with nonmanufacturing data (by Zu et al. or the others) may also raise questions of external validity/statistical generalisability. However, the study by Zu et al. (2008) is important to the researcher on two counts. Firstly, the study fits the parallel structure idea posited by Schroeder et al. (2008) and both Zu et al. (2008) and Schroeder et al. (2008) posit Leadership as the driver. Secondly, the TQM core articulated by Zu et al. (2008) could include Lean (under process management) and structured problem-solving and process management could merge into the concept of LSS.

In the opinion of the researcher, Schroeder et al. (2008) provide significant opportunities to improve SS theoretical development. The model, however, fails to consider situational factors, such as the complexity, uncertainty, and maturity of the project that can influence the relationship between SS implementation and performance. It may be argued that the Strategic Project Selection concept/construct advanced by Schroeder et al. (2008) incorporates some of the situational factors (e.g., project risk assessment and mitigation). Relative to Zu et al. (2008), Schroeder et al. (2008) provide a stronger emphasis on the culture. In contrast Zu et al. (2008) seems to offer a more structured process-oriented approach. Finally, while Schroeder et al. (2008)'s model could be used to explain successful and unsuccessful project implementations (e.g., wrong project choice, less engagement of the leadership for a particular project) within an organisation, the same cannot be said with Zu et al. (2008)'s model as this model does not seem consider the fact that there is significant variation between projects within the same organisation. This raises an important question in theories/models: the boundary conditions of the theory, which is explained in detail in section 3.5.1.

***Models that Used Knowledge Management as Theory to Explain SS Phenomenon***

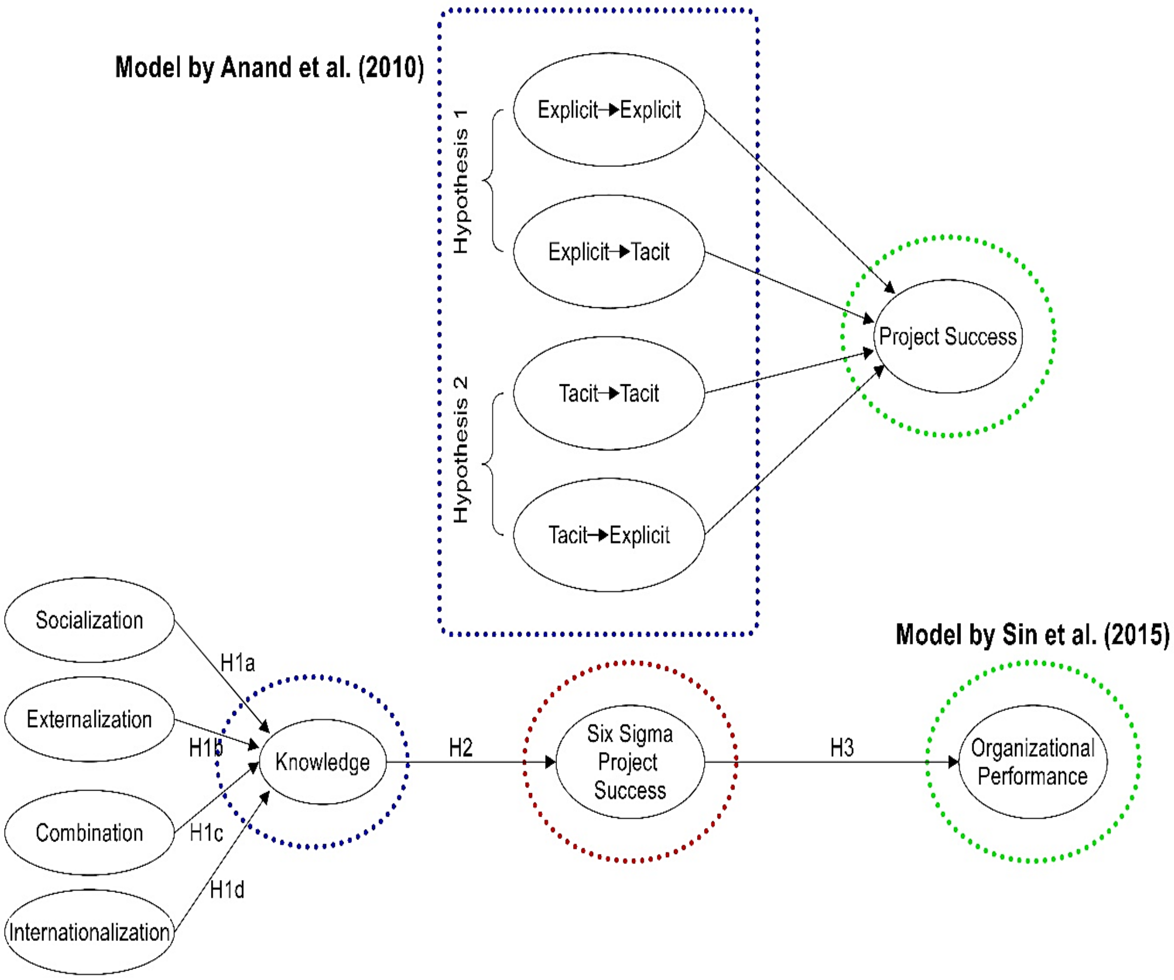


**Figure 2.9 Models incorporating knowledge management as theory to explain SS (Adapted from: Anand et al. , 2010)**

Using a knowledge management lens Anand et al. (2010) utilised Nonaka's (1994) theory of knowledge creation to evaluate the effectiveness of SS projects. Their model is consistent with the notion that SS projects typically seek to solve problems and improve processes, which necessitates a comprehensive understanding of the processes involved in the project (hence knowledge). Further, the emphasis on explicit and tacit knowledge in their model emphasises that SS teams need both documented information and the experiential insights of team members. Anand et al. (2010) also emphasise that organisations must embrace a knowledge-centric approach to promote a culture of CI and innovation in SS initiatives. This model, however, overlooks the direct impact the CI culture may have on SS projects, as well as other crucial factors such as Leadership engagement.

Sin et al. (2015b) used "knowledge-based theory of the firm" and Nonaka’s knowledge creation theory (Nonaka, 1994) as theoretical lenses to explain how knowledge is acquired to achieve organisational performance. Sin et al. (2015b) developed and tested a simple but powerful model to explain why SS leads to organisational performance (Figure 2.9). They used Nonaka’s organisational knowledge creation theory (Nonaka, 1994) to posit that knowledge is created by four forms of knowledge conversion: socialisation, externalisation, combination, and internalisation. Their model was found to be a good fit to data based on their structural equation modelling (SEM) analysis of data collected from 225 SS manufacturing firms. Although, their hypotheses were supported by data, their study did not report a detailed operationalisation of the constructs or the context of the manufacturing firms (e.g., country/countries to which the firms belong). In addition, it must be mentioned that whilst Arumugam et al. (2015) used goal theory as their principal theoretical lens, they also used knowledge management as a theoretical lens to develop their theoretical model. Use of multiple theoretical lenses—and strangely enough no theoretical lens—is not uncommon in theory development in applied research, as demonstrated by Niederman & March (2019).

### 2.4.3 LSS Models

Research on LSS has largely focused on prescribing Critical Success Factors (CSFs) or developing frameworks to implement LSS rather than exploring causal mechanisms (e.g., Yadav and Desai, 2017, Raval et al., 2018 and Vallejo et al., 2020). While such research does not qualify as “models” for this literature review, there are a few models that attempt to explain how LSS works. However, in these few models some constructs crucial for understanding how LSS works remain conspicuously absent (Perera et al., 2021a; Perera et al., 2021b). The work of Sim et al. (2021), Ahmed et al. (2022) and Muraliraj et al. (2020) are typical.

***Models Based on the Hypothesis LSS Practices → Improved Quality***

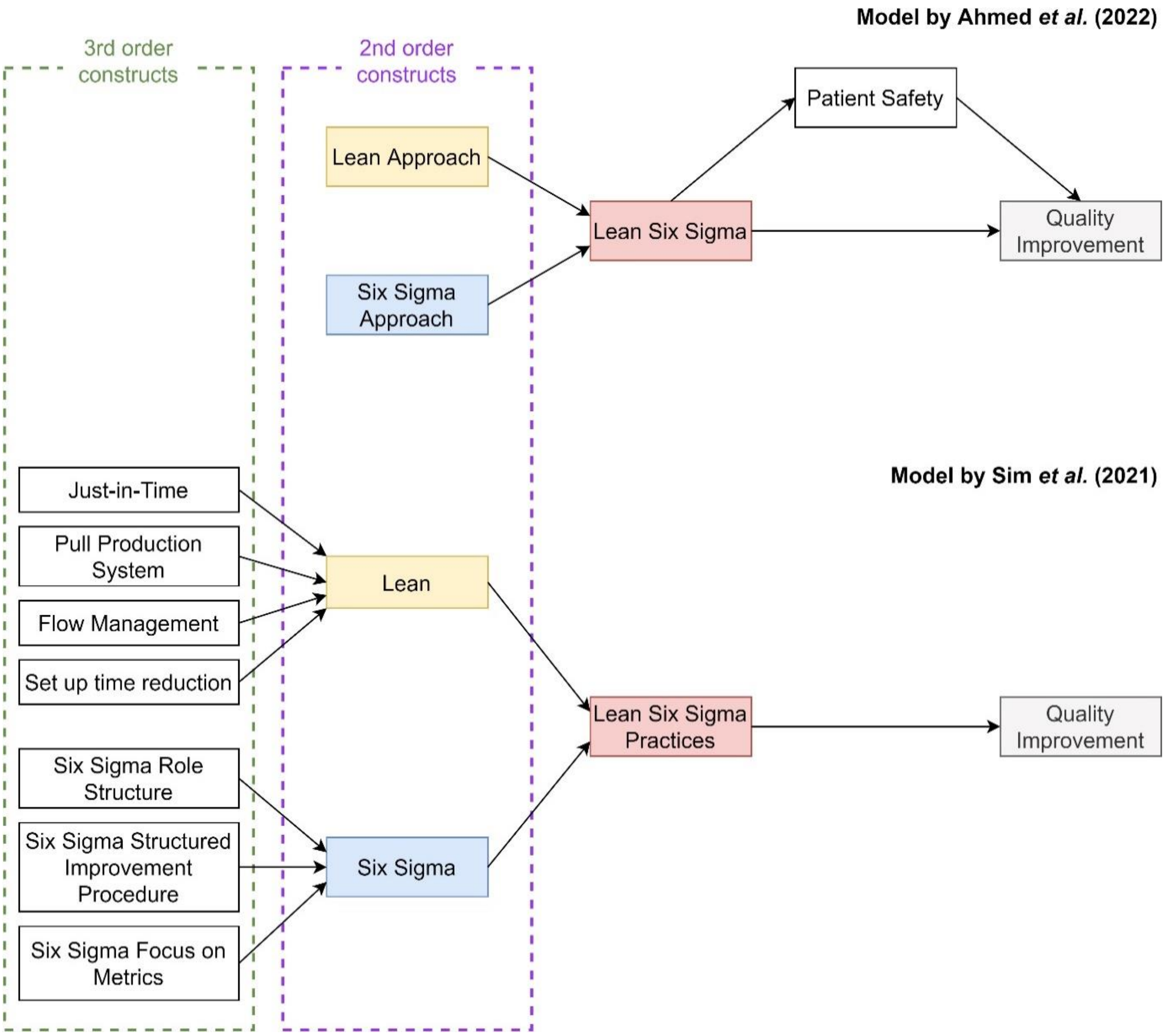


**Figure 2.10 Models focused on LSS practice on quality improvement (Adapted from: Ahmed et al., 2022; Sim et al., 2021)**

The two selected models are shown in Figure 2.10. Despite the fact that Ahmed et al. (2022) and Sim et al. (2021) research LSS principles in different contexts (healthcare and medical device manufacturing respectively), the research approach is similar in both studies. In the model advanced by Ahmed et al. (2022), the primary focus is on the role of Lean and SS practices in enhancing patient safety and improving hospital quality (Figure 2.10). For healthcare, Ahmed et al. (2022) tested the hypothesis that LSS Practices lead to Quality Improvement both directly as well as through Patient Safety (the moderator). In this study LSS Practices have been treated as a second-order construct that reflects the two first order constructs: Lean Practices and SS Practices. According to Ahmed et al. (2022), LSS practices are crucial for reducing errors in healthcare settings and improving the overall quality of patient care. It is evident from the study that LSS tools and techniques can be integrated into healthcare operations, reducing the risk of medical errors, improving patient safety, and optimising processes as a result.

Sim et al. (2021) posited and tested the hypothesis that LSS Practices lead to Quality Performance, with LSS Practices being presented as a third-order construct, whose second level is formed by the two constructs labelled Lean and SS, which are in turn formed from respective practices (e.g., JIT, pull product etc. for Lean). It is important to note that in both models shown in Figure 2.10 there is only one predictor (explanatory construct). To the left of the predictor are the operational definitions (measurement models). In both models behavioural constructs such as leadership and people, which are central for quality/process improvement, are not represented. Also, it is important to note that Sim et al. (2021) operationalise LSS to manufacturing and their measurement in all likelihood does not apply for services and many other nonmanufacturing contexts (e.g. JIT, pull system, setup time reduction etc are manufacturing-specific practices) and the same can be said about the operationalisation used by Ahamed et al. (2022) in that their operationalisation does not seem to apply well to manufacturing. This again is a question of the boundary condition of these studies.

***Models that Posit DMAIC as the Explanatory Construct of Performance***

The two selected models are shown in Figure 2.11. Although the response (explained construct) is not shown in the models, it is clear from the authors' descriptions that DMAIC is the predictor (explanatory construct) of performance, and hence the two models pass the researcher's inclusion criterion for review. Sreedharan & Sunder (2018) presents a novel approach to LSS project management that combines a conceptual framework with empirical evidence. In their model, Lean and SS methodologies are integrated into project management principles through the application of LSS methodologies. The DMAIC framework identifies critical elements such as process mapping, root cause analysis, and structured problem-solving methods. Through the amalgamation of best practices from both Lean and SS, the model provides organisations with a roadmap to effectively manage LSS projects to achieve performance outcomes. Sreedharan & Sunder (2018) enhanced the credibility of their framework by applying it to two practical case studies in a manufacturing setting. This application in real-world scenarios serves as vital empirical evidence, reinforcing the effectiveness of their model. Through this empirical testing, they demonstrated the practicality and robustness of their approach, grounding their theoretical framework in tangible, real-world results.

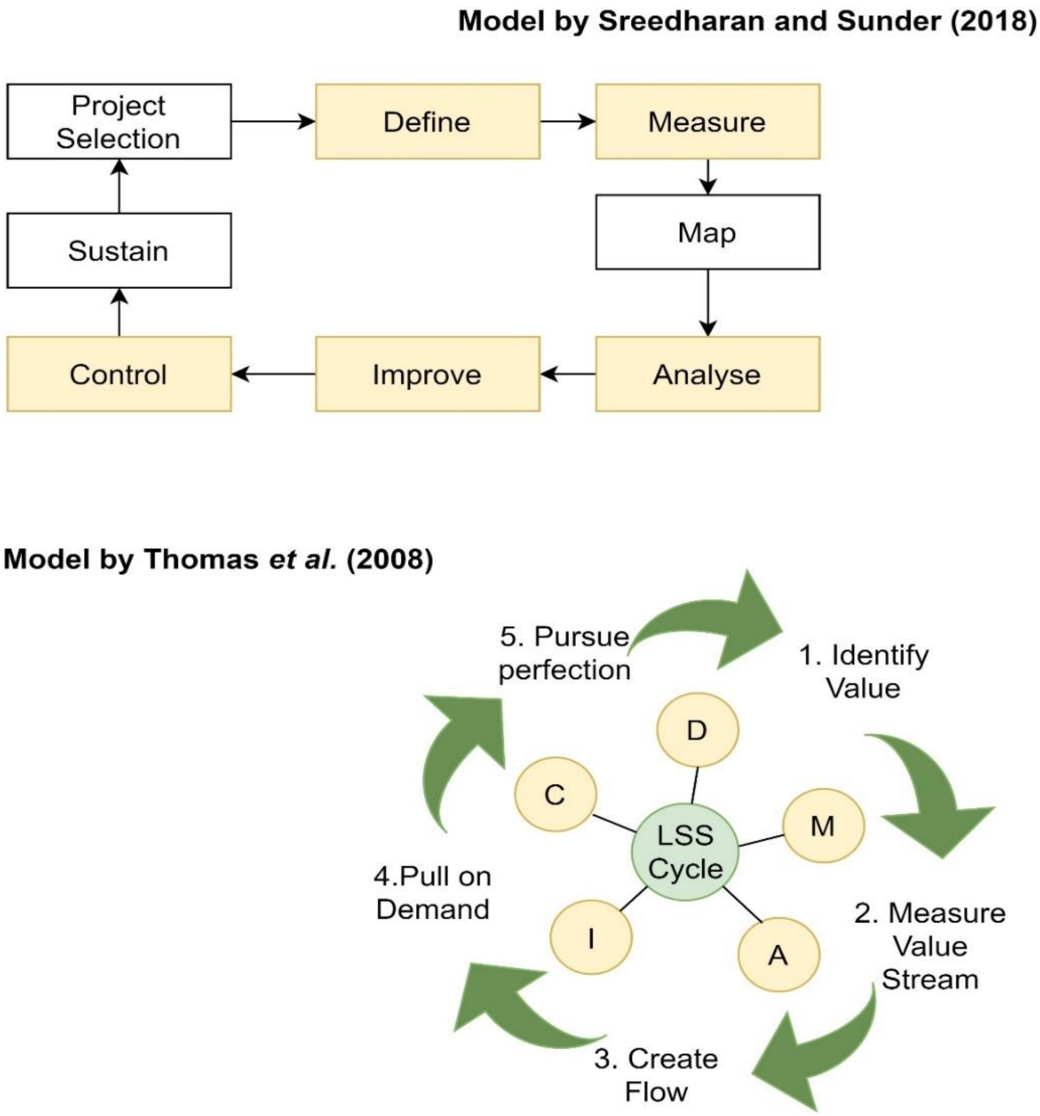


**Figure 2.11 Models focused DMAIC as the explanatory construct of performance (Adapted from: Sreedharan & Sunder, 2018; Thomas et al., 2008)**

The LSS model was posited by Thomas et al. (2008) for small to medium enterprises (SMEs) to explain how LSS implementation in the proper sequential way leads to change (the word “change” was used by the authors to mean substantial improvements to the processes and outcomes).  The model was tested for tenability in a small manufacturing form. According to the model, LSS implementation is characterised by a phased approach involving the DMAIC process embedded in Lean principles to streamline processes and reduce waste. One might question how this study passed the researcher’s inclusion criterion! According to Thomas et al. (2008), their model addresses some unique challenges and resource constraints faced by smaller organisations. Similarities exist between these two studies included in this section in that the models posited in both studies integrate the DMAIC methodology into process improvement, align methodologies with organisational objectives, and qualitatively validate the models with manufacturing case research data.

***Models that Posit LSS Constructs as Explanatory Variables of Organisational Capability***

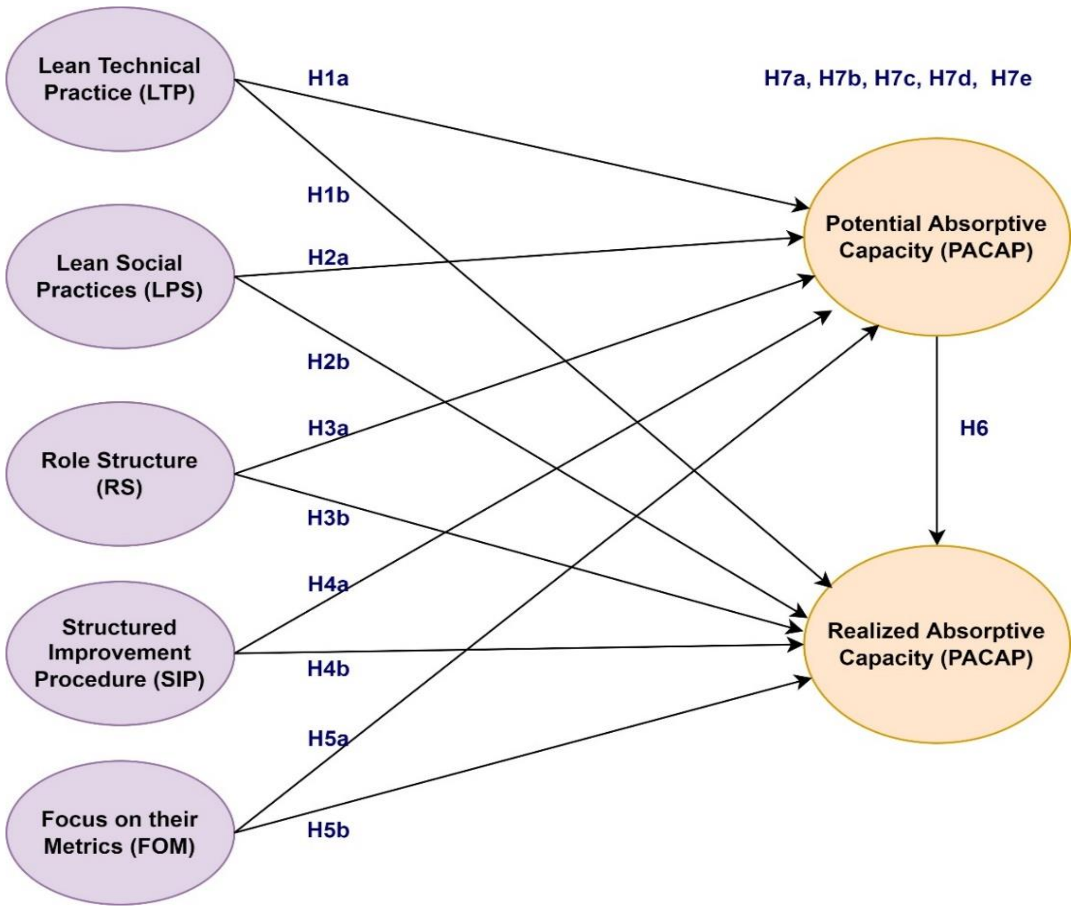


**Figure 2.12  LSS constructs as explanatory variables of organisational capability (Adapted from:  Muraliraj et al., 2020)**

Muraliraj et al. (2020) developed a framework exploring the integration of Lean and Six Sigma practices with the concepts of potential and realised absorptive capacity in Malaysian manufacturing organisations. The study investigates the relationship between Lean and Six Sigma practices and both potential absorptive capacity (PACAP) and realised absorptive capacity (RACAP), using SEM as their empirical testing method. It shows that specific Lean and Six Sigma practices positively influence both PACAP and RACAP, offering practical insights for implementing LSS to enhance absorption capacity effectively. The study provides practitioners with valuable insights on how to prioritise the implementation of LSS practices to enhance absorption capacity in diverse ways. Even though Muraliraj et al. (2020) have included a people aspect by examining the social practices associated with Lean, their main research purpose has been to examine how the distinctive practices of Lean and SS relate to 'potential absorptive capacity' and 'realised absorptive capacity'. The authors provide an overview of the major research lines in this area, rather than presenting a specific model. They also identify gaps in the existing literature and suggest areas for future research. These studies are useful for academics and practitioners who want a deeper understanding of the intersections between these three management systems and the challenges they pose.

***Models that Focus on the Enablers of Successful LSS Implementation***

Raval et al. (2018a) and Pal Pandi et al. (2014) propose models on LSS implementation that focus on understanding the interactions between various enablers. Another commonality between these two models is the use of Interpretive Structural Modelling (ISM) techniques for dissecting complex systems. Raval et al. (2018a) used ISM and Fuzzy Matriced Impacts Croisés Multiplication Appliquée à un Classement (fuzzy MICMAC) technique to understand the dynamics of LSS implementation within organisations. Similarly, Pal Pandi et al. (2014) used ISM to analyse the intricate relationships between CSFs aimed at enhancing the quality of engineering education institutions. The two models share an inherent emphasis on identifying and comprehending the key factors that have a significant impact on their respective fields.

There is, however, a significant difference between these models based on the application domains in which they are deployed. With an emphasis on LSS enablers, Raval et al. explore the enhancement of LSS implementation within organisational settings. To improve processes, organisations need insights into enabler interactions, which is what their model provides. On the other hand, Pal Pandi et al. (2014) focused on the Integrated Educational Quality Management System (IEQMS) which targets holistic improvement of engineering education institutions by casting a wider net. As part of this comprehensive framework, an array of global quality management practices, including ISO standards, SS, Lean thinking, and more, are incorporated, and tailored specifically for educational contexts.

Although both models share some similarities, due to their differing scopes and objectives, they exhibit various levels of complexity. The model presented by Raval et al. (2018) identifies 40 LSS enablers based on an extensive literature review and expert opinions, then creates a hierarchical model. These numerous LSS enablers can be intricate and interdependent, making the model very complex. A further layer of complexity is added by distinguishing between strategic and performance-oriented enablers by considering driving and dependence power. In Pandi et al. (2014)'s model, the IEQMS, emphasises quality management in engineering education institutions in a comprehensive way. This combines multiple quality management dimensions into a complex framework.

## 2.5 A 30,000-foot Perspective on LSS

Having reviewed a wide range of LSS literature including literature on LSS models and theories, the following big picture of LSS can be drawn.

### 2.5.1 Synergy within LSS: LSS > Lean + SS

One stream of literature focuses on the convergence of Lean and SS methodologies, capitalising on their respective strengths to draw synergies in achieving superior performance. The literature suggests that the synergy between Lean and SS resides in their shared focus on process optimisation and waste elimination, albeit through distinct problem-solving approaches—for example. DMAIC for SS and the five principles of Womack and Jones (1996) for Lean (George, 2002). The proponents of LSS argue that seamless integration of Lean's principles of efficient process flow with SS's analytical rigor for reducing process variations positions LSS as a versatile and adaptable approach, equipped to address both inefficiencies and quality challenges inherent in processes.

### 2.5.2 Theoretical Frameworks on LSS

Another stream of literature focus on theoretical model building and testing and the studies were covered in section 2.4.3. These models tend to isolate Lean constructs and SS constructs to posit that Lean practices and SS practices when combined (e.g., at an abstract level to form a higher-order construct which could be labelled as LSS or LSS practices) lead to quality performance or some other aspect of performance such as the organisation's absorptive capacity (e.g., Muraliraj et al., 2020). Despite SS's DMAIC framework remaining central to LSS, which identifies issues, implements solutions, and sustains control, it's essential to adapt the approach to organisational contexts for optimal results (Muraliraj et al., 2020; Thomas et al., 2016). Based on the LSS models reviewed in this section, SS's statistical analysis, hypothesis testing, and control mechanisms harmonise with lean principles of value stream mapping, standardised work, and continuous flow (Alblooshi et al., 2022; Burneo-Celi & Temblador-Perez, 2018; Sony et al., 2020b). In addition, the researcher argued that some models on SS (e.g., Schroeder et al, 2008) are more easily modified to represent an LSS context than the others.

### 2.5.3 Discriminant Validity of LSS

The literature on the theoretical underpinnings of Lean was found to be anchored in the TPS. The TPS/Lean is a production system that aims to reduce nonvalue adding activities and waste from every aspect of a firm's operation, in order increase customer value. This overarching aim was found to be applicable to manufacturing and nonmanufacturing organisations. For example, the five steps/principles of Lean advanced by Womack and Jones (1996) based on the TPS seem to be applicable across many organisations, not just manufacturing organisations, although at a very abstract level the TPS is founded upon JIT and respect for people. Although JIT and its associated concepts such as pull production have limitations in generalisability in some (if not many) nonmanufacturing contexts, the literature on Lean as well as LSS seem to suggest that the five steps/principles of Lean advanced by Womack and Jones seem to have generalisability across both manufacturing and nonmanufacturing contexts.

The literature on the theoretical underpinnings of SS was found to be anchored in different theoretical lenses with goal theory being a common theory to be used to derive theoretical models on SS to explain how the structured problem solving (DMAIC) happens in SS to achieve superior product and service performance (e.g., quality performance). When unifying Lean and SS concepts under the umbrella concept LSS to draw synergies of both these customer driven concepts (SS has a strong financial focus too), which sems to be an attractive proposition for the practitioner, the following academic question can be raised: “is LSS reliably distinguishable from Lean and SS to warrant its theoretical justification?”. This question, which is a question of *discriminant validity* in a quantitative research sense, is particularly relevant to situations (projects) that are positioned at the extremes of the LSS continuum (Figure 2.13). That is, projects that are dominated by Lean or SS practices but not both. Researchers who have used quantitative research techniques such as SEM seem to have addressed this question by demonstrating that Lean and SS are theoretically distinguishable concepts (constructs) as their model passed the tests for discriminant validity. However, there is apparent lack of depth in these theorisations because representing Lean as a single construct and SS as a single construct to form or represent the more abstract concept LSS does not provide (arguably) the adequate causal predictiveness to explain or predict how the requisite performance is caused through LSS implementation. One question associated with this lack of depth is where to start and what drives the requisite performance? Positing and supporting the hypothesis that the requisite performance is caused by the construct LSS (though useful), probably does not represent a very good theory, because such a theorisation does not incorporate mediators or moderators to present a more elaborate causal mechanism (for an answer to the question "what constitutes a theoretical contribution?", see Corley & Gioia, 2011; Whetten, 1989).


**Figure 2.13 The LSS continuum**

## 2.6 Knowledge Gaps

The literature review leads to the following three interrelated knowledge gaps.

### 2.6.1 The Need to Integrate Overlapping Theoretical Perspectives to Develop a Testable Theory on LSS (Knowledge Gap 1)

While the theoretical model posited by Schroeder et al. (2008) on SS looked promising, there is no evidence to suggest that their model has been further developed and empirically tested as a theory on SS or LSS. The researcher argued (section 2.4.2→ Models that used culture/context to explain SS phenomenon) that the aforesaid model aligns with many LSS characteristics, such as the strategic selection of projects and the need for improvement specialists like black and green belts, utilising structured problem-solving methods. However, a notable limitation identified is the model's omission of project-related contingency variables, deemed significant by other researchers (e.g., Linderman et al., 2003 Arumugam et al., 2016). The researcher (the author of this thesis) analysed the existing literature and gaps (generalisation boundaries) in most studies (both on model building and model testing) that attempted to develop and test empirical models on SS and LSS. The present author could not find any study that attempted to develop or test an explicit theory on LSS. The models on LSS (e.g., Ahmed et al., 2022; Sim et al., 2021) seem to take the position that performance is caused by the LSS construct (section 2.5.3), which the researcher critiqued on the lines of the inadequacy of a theoretical contribution.

This research aims to fill the gap in the existing literature by synthesising and reconciling the overlapping perspectives embedded in Lean and SS to demonstrate that there is such a thing as LSS, which is reliably distinguishable from Lean and SS. Hence it is imperative to develop a theoretical framework that captures both Lean and SS methodologies to represent LSS as a standalone methodology. Such integration is crucial to gaining a comprehensive understanding of how Lean and SS—or more specifically LSS—work within different organisational contexts. Developing a theory/model to explain how improvement is caused by implementing LSS will provide a better explanation of how overlapping perspectives are accommodated within LSS. Conceptual model development in Chapter 3 discusses the necessity of integrating these overlapping theoretical frameworks, emphasising the importance of building a testable theory that combines the foundational principles of not only Lean and SS but also other perspectives, most notably project management.

### 2.6.2 Goodness-of-Fit of LSS to Manufacturing Versus Nonmanufacturing (Knowledge Gap 2)

Very few scholars disagree that Lean is based on TPS. Some TPS practices such as pull production, JIT, setup time reduction, TPM, and several others cannot be applied to nonmanufacturing environments However, to the TMC's credit, they have made public (through the announcement of the TW) that Toyota's core values and guiding principles of the TPS are based on two high-level principles: respect for people and continuous improvement. In testing this proposition with Toyota’s sales and marketing data, Jayamaha et al. (2014) represented respect for people as people development and continuous improvement as process management. These high-level concepts of the TPS as well as Womack and Jones’ five Lean principles make Lean generalisable across service and nonmanufacturing sectors.

Similarly, to the above, very few scholars would disagree that the underlying concepts of SS are derived from manufacturing concepts. In manufacturing, for example, it is much easier to achieve a 3.4 DPMO process capability level or a 2.0 CPK index (depending on assumptions) by designing planned experiments to reduce variation or any other method that reduces variation to unprecedented levels by reducing variation. However, once SS is translated into a leadership-driven structured problem-solving method of CI, SS becomes applicable to nonmanufacturing. A translation of manufacturing concepts into nonmanufacturing poses two questions. To present LSS as a theory (or approach in lay language) generalised across both manufacturing and nonmanufacturing, there is a question about how much is lost in translating manufacturing ideas or concepts to nonmanufacturing. Considering that nothing is lost in translation, does LSS still fit better in manufacturing than nonmanufacturing?

### 2.6.3 The Need to Harness the Literature on CSFs of LSS towards LSS Theorical Model Building (Knowledge Gap 3)

The third significant gap recognised the abundance of publications on CSFs of LSS, without anybody making a serious attempt to synthesise these publications to identify broader concepts of LSS leading the LSS model building. When explaining LSS outcomes, it is not possible to ignore CSFs since they are the determinants of LSS project success. In LSS literature, the focus of the academic community has mainly been on, either prescribing critical success factors (CSFs) for LSS implementation or reviewing past research on this topic (e.g., Laureani et al., 2012 Hilton et al., 2012 Sreedharan et al., 2018 Costa et al., 2018 Cherrafi et al., 2016. However, the downside of including CSFs as theoretical constructs to explain LSS as a project management/success phenomenon is that there are too many CSFs available to constitute a parsimonious theory (e.g., Hilton et al., 2012 mentions 23 CSFs under five headings; Cherrafi et al., 2016 mentions 9 CSFs). Moreover, the CSFs prescribed for Lean, SS, and CI are too many and poorly defined. These factors encompass a range of dimensions, including leadership commitment, employee engagement, effective change management, data-driven decision-making, cross-functional collaboration, and alignment with organisational strategy. Scholars have identified these CSFs across various industries, highlighting their significance in achieving desired LSS outcomes (Antony et al., 2012; Pal Pandi et al., 2014).

While individual CSFs have been extensively studied, there is a growing recognition of the need to consolidate and integrate these factors into a comprehensive theoretical model. Such a model would not only provide a holistic perspective on LSS implementation but also offer a structured framework for organisations to navigate the complexities of LSS adoption. The development of a theoretical model that synthesises CSFs in LSS implementation offers several distinct benefits. Firstly, it would provide a unified framework that clarifies the interdependencies and interactions between numerous factors. Secondly, such a model could guide organisations in prioritising CSFs based on their contextual relevance and strategic objectives. Thirdly, the model could facilitate the identification of gaps and areas of improvement in existing practices, enabling organisations to refine their approach to LSS implementation. The construction of a theoretical model that encapsulates LSS CSFs bridges the gap between academic research and practical implementation.

## 2.7 Chapter Summary

An extensive literature review of LSS is provided in this chapter. Due to the way LSS is defined and practiced, the literature review had to cover the literature on Lean, SS, and LSS with the primary focus on the theoretical underpinnings of these three related, but hopefully sufficiently discrete theoretical underpinnings (distinguishability of LSS from Lean and SS is a question that is addressed and resolved at the research design and execution stage). The literature review on LSS suggested that LSS is presented as a single construct (often labelled as LSS practices) that predicts and explains performance. While this theorisation cannot be disparaged, the researcher pointed out that from a causal predictive sense this theorisation is inadequate because the theory does little (if any) to explain or predict how (improved) performance is caused through LSS implementation. One question associated with this lack of depth is where to start and what drives the requisite performance? (section 2.5.3 and the knowledge gap shown in section 2.6.1).

Both Lean and SS were found to be manufacturing centred ideas or concepts, but the literature review suggested that sufficient generalisations have been made by scholars to make these ideas or concepts applicable to both manufacturing and nonmanufacturing. More specifically, it was found that while the nuts and bolts of Lean that stem from the TPS—pull production, JIT, setup time reduction, TPM and several other practices—are manufacturing centric, once Lean is represented as a theory on CI to reduce waste and nonvalue adding activities to increase customer value, it becomes generalisable across both manufacturing and nonmanufacturing. On the same token it was found that while the nuts and bolts of SS—understanding and reducing variation of a quality characteristic to unprecedented levels—stem from manufacturing (it would be hard to measure quality in nonmanufacturing, especially services because quality is subjective and much depends on how the customer perceives the experience in the exchange of value), once SS is represented as a theory on improving performance through structured problem solving driven by the leadership in a CI culture/climate, it becomes generalisable across both manufacturing and nonmanufacturing. These translations were shown to pose some problems (knowledge gap 2 shown in section 2.6.2).

Finally, the literature review found that a large volume of literature exists on peer-reviewed studies that prescribe critical success factors (CSFs) of LSS implementation success. In a theoretical sense, CSFs are determinants of LSS once the pool of CSFs that scholars have prescribed are reduced to manageable components (not yet completed and published outside of the author and her supervisors for this study) in a meaningful way (knowledge gap 3 as illustrated in section 2.6.3). The researcher contends that the literature on the CSFs on LSS is theory, as far as her research is concerned. Fortunately, or unfortunately, the current body of literature on the CSFs on LSS is so vast that treating this domain warranted another half a chapter of literature review chapter (next Chapter). The outcome of this review led to a novel way of synthesising knowledge (Machine learning) that was directed towards conceptual model building with the support of the knowledge synthesised from the review of extant models of SS and LSS (details in the next chapter).

The nexus between the knowledge gaps and the research questions is shown in Figure 2.14.

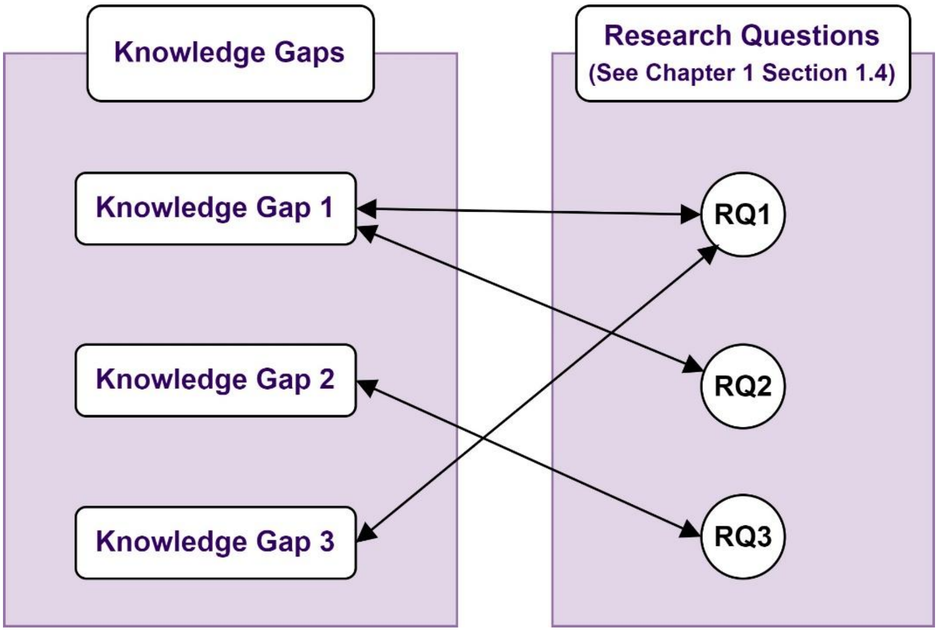


**Figure 2.14 The nexus between knowledge gaps and research questions**

# CHAPTER 3
# DEVELOPMENT OF CONCEPTUAL MODEL

## 3.1 Introduction

In formulating a theoretical model, three key basic requirements must be met: establishment of theoretical constructs, the delineation of relationships between these constructs based on temporal asymmetry, and the specification of the model's generalisability boundaries (Byron et al., 2016; Dubin, 1978; Whetten, 1989). This research, which uses a *project management lens*, consists of five phases (Figure 3.1). Phase 1 of the research covers the exploration of existing literature pertaining to the research aim, which included the review of literature on theoretical models on Lean, SS, and LSS to identify the knowledge gaps (study Phase 1 shown in Figure 3.1). A detailed coverage of this preliminary phase was provided in the previous chapter.

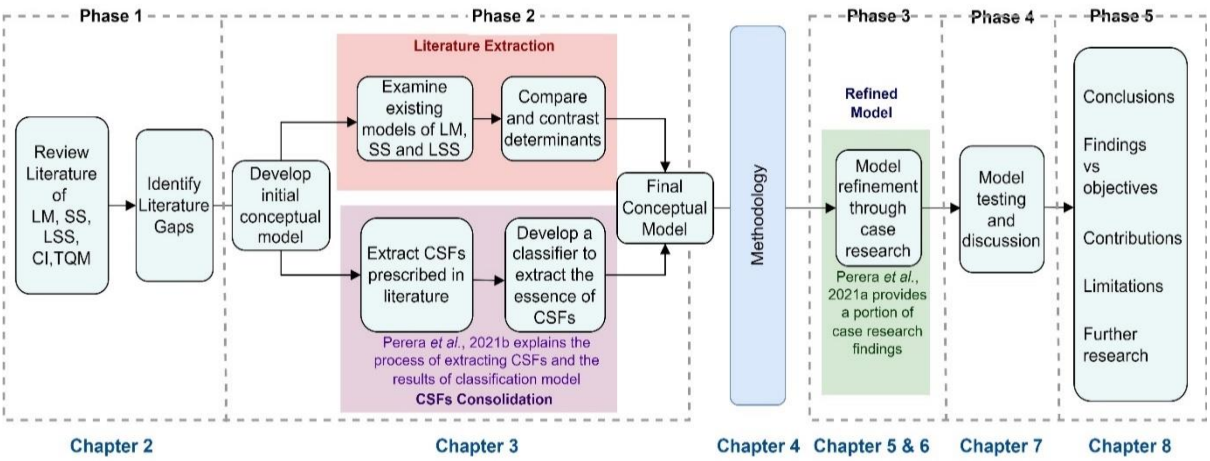


**Figure 3.1 Key stages of the research process**

This chapter explains the second phase of the research which covers the systematic process used to develop the final conceptual model that underpins study. This includes developing an initial conceptual model, developing the theoretical concepts, propositions associated with the concepts, and specifying the generalisability boundaries of the propositions. The researcher would not call the final conceptual model (the output of Phase 2 of the study) as her theoretical model because the conceptual model went through further development through fieldwork (Phase 3) to make the model testable (i.e., conversion of concepts into constructs by adding the required level of abstraction by operationalising the concepts). One of the main outputs of

Phase 3 of the study is the theoretical model that was tested in the next phase (Phase 4). The remainder of this chapter is organised as follows. Development of the initial conceptual model (Figure 3.2) is presented in section 3.2. The initial conceptual model is developed based on the rudimentary axiom of project management — the iron triangle — which holds that to achieve quality, timely completion, and cost efficiency, a project must be planned and executed efficiently and effectively (Atkinson, 1999; Gardiner et al., 2000).

Using the initial conceptual model as a base, the researcher went on to augment the model using two parallel approaches. Firstly, the researcher revisited the Lean, SS, and LSS models reviewed in the previous chapter from a project management lens (section 3.3). Secondly, and almost parallelly, an innovative ML algorithm was employed to consolidate a large volume of literature on CSFs of Lean, SS, and LSS (section 3.4) to gain insights on the determinants of LSS.[6] The latter work has been published in Perera et al. (2021b). The reason behind using the two parallel approaches was to merge the findings of the two approaches (both approaches attempt to synthesise the determinants of LSS) to develop the final conceptual model to suit the project management context (section 3.5). The project management context also becomes an important aspect in specifying the boundaries of the conceptual model, and therefore the boundaries of the present study.

## 3.2 The Initial Conceptual Model

Figure 3.2 portrays the initial conceptual model highlighting project initiation and project execution — the latter leading to quality performance and customer satisfaction (the immediate outcomes of the LSS execution processes) which is posited to be positively related to business performance. Business performance of an LSS organisation does not improve by successfully implementing just one LSS project achieving the expected return on investment but by implementing several LSS projects and doing other things right (e.g., selecting the right product/service markets to compete in, anticipate changes in the environment, and implement requisite innovations and so forth). Thus, business performance receives a low profile in this research as a theoretical concept/construct under scrutiny.

[6] Although as many as 236 articles were considered in the review the literature on CSFs of LSS, the synthesis of the literature was done by a machine rather than a person. This is the reason why development of the conceptual model was not covered under the literature review.

LSS project implementation comprises two major segments: the initiation phase and the execution phase where transformation of inputs into outputs occurs. The result of the outputs are the outcomes, which are posited to be quality performance, customer satisfaction, and the expected returns on investment. This conceptualisation (inputs → processes→ outputs → outcomes) used by the researcher is consistent with systems theory and operational excellence (Cua et al., 2001; Found et al., 2018).

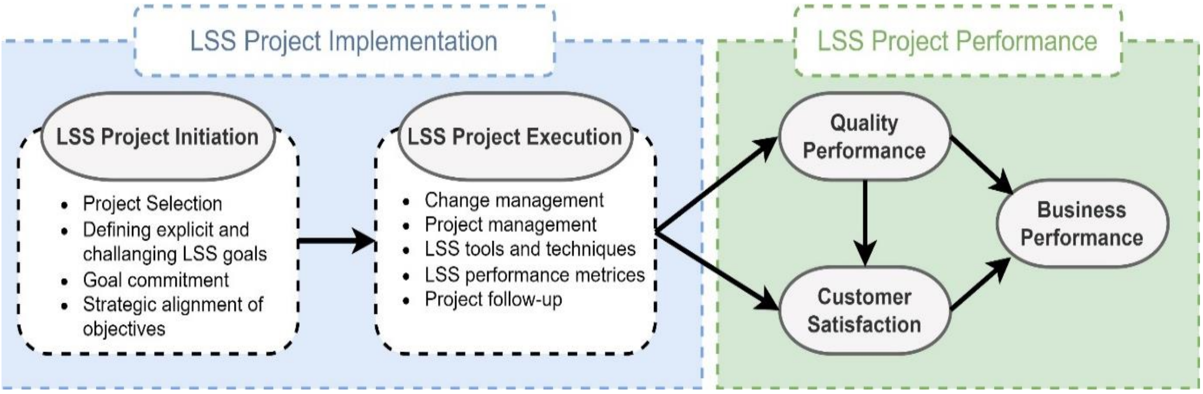


**Figure 3.2 The initial conceptual model**

The initiation and execution phases of LSS projects are critical stages where planning, scheduling, and the transformation of various inputs (e.g., knowledge, social interactions such as teamwork, and the application of tools and techniques for improvement) into outputs occurs, playing a vital role in the overall success of LSS deployment (Antony et al., 2007; Psychogios, 2012; Snee, 2010). In the LSS project initiation phase, crucial activities such as planning and scheduling set the stage for successful project execution, where process inputs like knowledge, social interactions, and the application of improvement tools and techniques are converted into valuable outputs. To select projects effectively, it is essential to consider the 'voices' of the customer, the business, the process, and the stakeholders (Antony et al., 2007; Sreedharan & Sunder, 2018). Furthermore, the role of organisational leadership and LSS culture extends beyond these phases, significantly impacting LSS deployment success (Linderman et al., 2003; Schroeder et al., 2008; Sin et al., 2015). Leadership's role in goal setting is highlighted by goal theory, emphasising the need for goals to be clear, challenging, aligned with organisational strategy, and supported by commitment from organisational members (Arumugam et al., 2016; Linderman et al., 2003). Thus, the success of LSS deployment is not merely the outcome of its initiation and execution phases but a collective result of various factors including effective project selection, leadership goal setting, and the cultivation of an LSS culture, as illustrated in Figure 3.2.

Schroeder et al. (2008), Zu et al. (2008) and many others equated SS execution to problem solving involving define → measure → analyse → improve → control (DMAIC) stages. Consequently, performance matrices (the measure stage of DMAIC), tools and techniques (Measure, Analysis, and Improve stages of DMAIC), and project follow-up (control stage of DMAIC) come into play in SS/LSS execution (Antony et al., 2017; Schroeder et al., 2008). The researcher also considers change management and project management strategies in the LSS execution stage, in keeping with quality improvement and project management principles respectively (Hilton et al., 2012; Schroeder, 2008). In summary, the initial conceptual model posits that successful implementation of an LSS project (project initiation and project execution) will result in improved quality performance and customer satisfaction, which in turn positively influences business performance — more precisely, the expected return on investment of a particular project (Cherrafi et al., 2017; Kull & Wacker, 2010; Sousa & Voss, 2002; Zu et al., 2008).

## 3.3 LSS Literature Extraction: Revisiting Lean, SS, and LSS Models

Conducting a literature review of existing literature is the fundamental step in developing a conceptual model (Albliwi et al., 2014; Wacker, 1998; Xiao & Watson, 2017). In this study, as mentioned earlier, the reviewed literature domains were Lean, SS, and LSS. To explain LSS project success, it is necessary to compare existing Lean, SS, and LSS models based on the concepts being used. The comparison process encompassed the analysis of 17 studies on SS and LSS models as well six studies on Lean models identified via the systematic literature review covered in Chapter 2. Table 3.1 list the theoretical concepts (or constructs) on Lean, SS, and LSS covered in the 23 studies. Numerous concepts/constructs emerge because studies differ in their focus as well theoretical lenses (only some studies mention the term theoretical lens) used.

The six Lean management models that have been listed attempt to explain how organisations can benefit from Lean principles. The emphasis of these models has been on Lean practices, structured methods, and efficiency (e.g., increase the throughput). Using financial metrics as a key construct, Fullerton et al. (2014) examined how Lean practices can align with cost accounting to explain how Lean practices affect financial performance. According to Jabbour et al. (2013), culture plays an integral role in the integration of human resources and lean manufacturing into environmental management. Both Sony (2018) and Tortorella & Fettermann (2018) focus on the relationship between Lean production and Industry 4.0 implementation. However, their models have only been empirically tested in the manufacturing sector. Similar to Jabbour et al. (2013), Yang et al. (2011) explore the interactions between Lean manufacturing, environmental management on business performance. They consider business performance and environmental management practices as critical constructs of model, given the scope of their study.

Studies on SS models attempt to either extend or complement TQM by highlighting how SS can be distinguished from TQM. Some studies use goal setting, other studies use the SS role structure, the use of specialists, and strategic project selection in SS to make this distinction (see Table 3.1). As with TQM, Leadership Engagement acts as the driver in most SS studies. In studies that do not use Leadership Engagement as a theoretical concept (or construct), the leadership's role is implied. For example, studies that use goal setting as the defining feature of SS implicitly recognise the role the leadership plays in goal setting. It is based on the concept that well-defined and ambitious goals, together with feedback and commitment and engagement of leaders, lead to improved performance (Baig et al., 2021; Silverthorne, 2001).

Studies on LSS models primarily attempt to explain and/or predict the achievement of performance goals via Lean practices and LSS practices (see Table 3.1). Despite this effort, certain critical constructs for understanding how LSS operates are missing (Perera et al., 2021b). Sim et al. (2021), Ahmed et al. (2022), and Muraliraj et al. (2020) are examples. Sim et al. (2021) posited and tested the hypothesis that LSS Practices lead to Quality Performance, with LSS Practices being presented as a third-order construct, whose second level is represented by a construct on Lean Practices and a construct on SS Practices. For healthcare, Ahmed et al. (2022) tested the hypothesis that LSS Practices lead to Quality Improvement both directly as well as the through Patient Safety (the moderator). Both models do not consider behavioural constructs such as leadership and people, which are central for quality/process improvement. Even though Muraliraj et al. (2020) have incorporated a people element by investigating the social practices associated with Lean, their main research focus has been on understanding the relationship of Lean with potential and realised absorptive capacity. Despite the wealth of anecdotal evidence, case studies, and the empirical models such as the ones covered above, there exists a need to develop and test a model on LSS that fills the gaps mentioned Chapter 2.

**Table 3.1 Concepts emphasised in extant models on SS, Lean, and LSS**

| LSS component | Literature | Goal setting | Project selection | Training | Leadership | Human Resource Focus | Specialists/ Experts | Role structure | Knowledge | Commitment | Lean Practices | SS Practices | Structured Method | Task Complexity | Quality performance | Business Performance | Performance* | Other** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS | Linderman et al. (2003) | √ | | √ | | | | | | √ | | | | √ | | | √ | |
| SS | Linderman et al. (2006) | √ | | | | | | | | | | | √ | | | | √ | |
| SS | Arumugam et al. (2016) | √ | | | | | | | √ | | | | √ | | | | √ | |
| SS | Schroeder et al. (2008) | | √ | | √ | | √ | √ | | | | | √ | | | | √ | |
| SS | Krueger et al. (2014) | | √ | √ | √ | | √ | √ | | | | | | | | | √ | |
| SS | Zu et al. (2008b) | | | | √ | | | √ | | √ | | √ | | | √ | √ | | |
| SS | Sin et al. (2015b) | | | | | | | | √ | √ | | | | | | | √ | |
| SS | Anand et al. (2010) | | √ | √ | | | √ | | √ | | | | | | | | √ | |
| SS | Chakravorty (2009) | | √ | √ | | | √ | | | | √ | √ | √ | | | | | |
| Lean | Sugimori et al. (1977) | | | | | | | | | | √ | | √ | | | √ | √ | √ |
| Lean | Shah & Ward (2003) | | | | | √ | | | | | √ | | | | | √ | √ | √ |
| Lean | Shah & Ward (2007) | | | | | | | | | | √ | | √ | | | √ | √ | √ |
| Lean | Jayaram et al. (2010) | | √ | | | | | | | | √ | | √ | | | | √ | √ |
| Lean | Shook (2010) | | | | √ | | | | | | √ | | √ | √ | | √ | | |
| LSS | Ahmed et al. (2022) | | | | | | | | | | √ | √ | √ | | √ | √ | | |
| LSS | Sim et al. (2021) | | | | | | | | | | √ | √ | √ | | √ | | | √ |
| LSS | Muraliraj et al. (2020) | | | | | | | √ | | | √ | √ | | | √ | √ | | |
| LSS | Pal Pandi et al. (2014) | | | √ | √ | | | √ | | | | √ | | | | √ | | √ |
| LSS | Raval et al. (2018a) | | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | | | | √ | |
| LSS | Sreedharan& Sunder (2018) | | √ | √ | √ | | √ | | | √ | √ | √ | | | √ | √ | √ | |

| LSS component | Literature | Goal setting | Project selection | Training | Leadership | Human Resource Focus | Specialists/ Experts | Role structure | Knowledge | Commitment | Lean Practices | SS Practices | Structured Method | Task Complexity | Quality performance | Business Performance | Performance* | Other** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LSS | Thomas et al. (2008) | | | | | | | | | | √ | √ | √ | | √ | | | √ |

* “Performance” is the label of the outcome construct in some studies. In most of these studies, performance means LSS project performance which may cover multiple performance metrics.

** “Other” means concepts/constructs that do not carry a concise name.

Before comparing the concepts shown in Table 3.1 with the concepts that emerged after the ML routine (Table 3.8), it becomes necessary to align the concepts shown in Table 3.1 with the concepts shown in the initial conceptual model (see Figure 3.2). This is because the concepts that emerged after the ML routine have been aligned with the initial conceptual model.

**Table 3.2: Concepts shown in Table 3.1 versus concepts shown in the initial conceptual model and general project management literature**

| Concept Shown in Table 3.1 | Concepts Shown in the Initial Conceptual Model and General Project Management Literature |
|---|---|
| Leadership Engagement | Project Leadership (Emerged from general literature) |
| Goal setting<br>Project selection<br>Commitment | LSS Project Initiation (From initial conceptual model) |
| Training<br>Human Resource<br>Specialists/ Experts<br>Role structure<br>Knowledge | Improvement Culture (Emerged from general literature) |
| Lean Practices<br>SS Practices<br>Structured Method | LSS Project Execution (From initial conceptual model) |
| Task Complexity | Project Contingency Variable/Factor (Emerged from general literature) |
| Quality performance<br>Business Performance<br>Performance | LSS Performance (From initial conceptual model) |

Having arranged the Lean, SS, and LSS models in a comparable format (Table 3.2), the researcher would now like to focus the readers' attention to the next parallel stage of phase 2: consolidating the CSFs of LSS, which features ML.

### 3.3.1 The Role of CSFs in Strategic Performance Management

CSFs are the elements of an organisational strategy that can influence the performance of the organisation while guiding it towards a positive direction (Alkarney & Albraithen., 2018; Bullen & Rockart, 1981; Maciel-Monteon et al., 2020; Vallejo et al., 2020). Rockart (1979) defined CSF as specific circumstances and variables that have a significant effect on the results and performance of an organisation. CSFs often play the role of evaluation criteria being elements that are essential for an organisation or project to achieve its mission (Albliwi et al., 2017; Clegg et al., 2010; Laureani & Antony, 2017b). Researchers have claimed that a CSF concept implies a direct correlation between pursuing satisfactory outcomes and performing specific activities in an organisation in a specific subject area such as CI (Alkarney & Albraithen,2018; Pathiratne et al., 2018). According to Alkarney & Albraithen (2018) and Ram& Corkindale (2014), CSFs are an attempt to systematically identify the key areas that management should evaluate and prioritise when implementing LSS initiatives to achieve desired performance goals. Thus, using the CSFs concept in organisational strategic activities is vital for managers and decision-makers as it provides guidance for successful LSS implementation initiatives (Pathiratne et al., 2018; Sreedharan et al., 2018b).

The evolution of quality management literature in the 1990s focused heavily on CSFs for TQM organisations, which subsequently transitioned to LSS in later years. During this time (1990's) Hietschold et al. (2014) synthesised these into 11 factors[7] through traditional methodologies such as literature reviews, meta-analyses, and focus groups. As the focus shifted from TQM to SS and LSS, the literature also evolved, with numerous peer-reviewed papers, mostly conceptual, exploring CSFs for successful LSS implementation (e.g., Hilton & Sohal, 2012; Jeyaraman & Kee Teo, 2010; Sreedharan et al., 2018b). The researcher observes a notable distinction between the CSF literature on TQM and LSS: there is a greater consensus among

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[7] The 11 factors are: "HRM/recognition/teamwork; top management commitment and leadership; process management, customer focus and satisfaction; supplier partnership; training and learning; information/analysis/data; strategic quality planning; culture and communication; benchmarking; and social and environmental responsibility" (Hietschold et al., 2014, p. 62-64).

TQM authors, likely because early TQM research pioneers (e.g., Ahire et al., 1996; Flynn et al., 1995) focused on papers on TQM theory building and testing, rather than conceptual papers of practitioner interest. This shift from a unified approach in TQM CSF literature to a more diverse exploration in LSS highlights the evolving nature of quality management research and the importance of adapting theoretical frameworks to suit the changing paradigms in organisational excellence.

## 3.4 Critical Success Factors of LSS and the Consolidation Process

### 3.4.1 Consolidation of the CSFs of LSS Project Success

To address the divergence in CSF literature on LSS, the researcher employed ML techniques in conjunction with traditional methods such as systematic reviews and expert consultations to consolidate CSFs. ML was deemed necessary to consolidate CSFs in a more effective and nuanced manner. This was because of the lack of consensus in the LSS and CSF literature. Initially, conventional approaches, such as systematic literature reviews and expert input, were employed to lay the groundwork for the ML phase. Details regarding the specific procedure for this process are provided in the following section. Even though TQM, Lean, and SS have distinct definitions, these systems often coexist within organisations and share similar performance objectives (Albliwi et al., 2014; Sreedharan et al., 2018b). In practice, CI is an integral part of all three systems. Therefore, the researcher views CSF literature across Lean, SS, LSS, TQM, and general CI implementations as complementary, drawing insights from various sources (Jeyaraman et al., 2010; Schroeder et al., 2008; Zu et al., 2008b). Hence, this study combines diverse methodologies, including advanced machine learning techniques with traditional approaches, to holistically study and consolidate CSFs across Lean, SS, LSS, and TQM, thus acknowledging their interconnectedness and common focus on CI.

Consolidating CSFs of LSS project success comprised two major elements as shown in Figure 3.3. The first element was mining the CSFs in the literature through a systematic literature review. The second element was to develop an ML classification model to extract the essence of CSFs harnessed in extant literature. Appendix A provides the python code for the classifier.

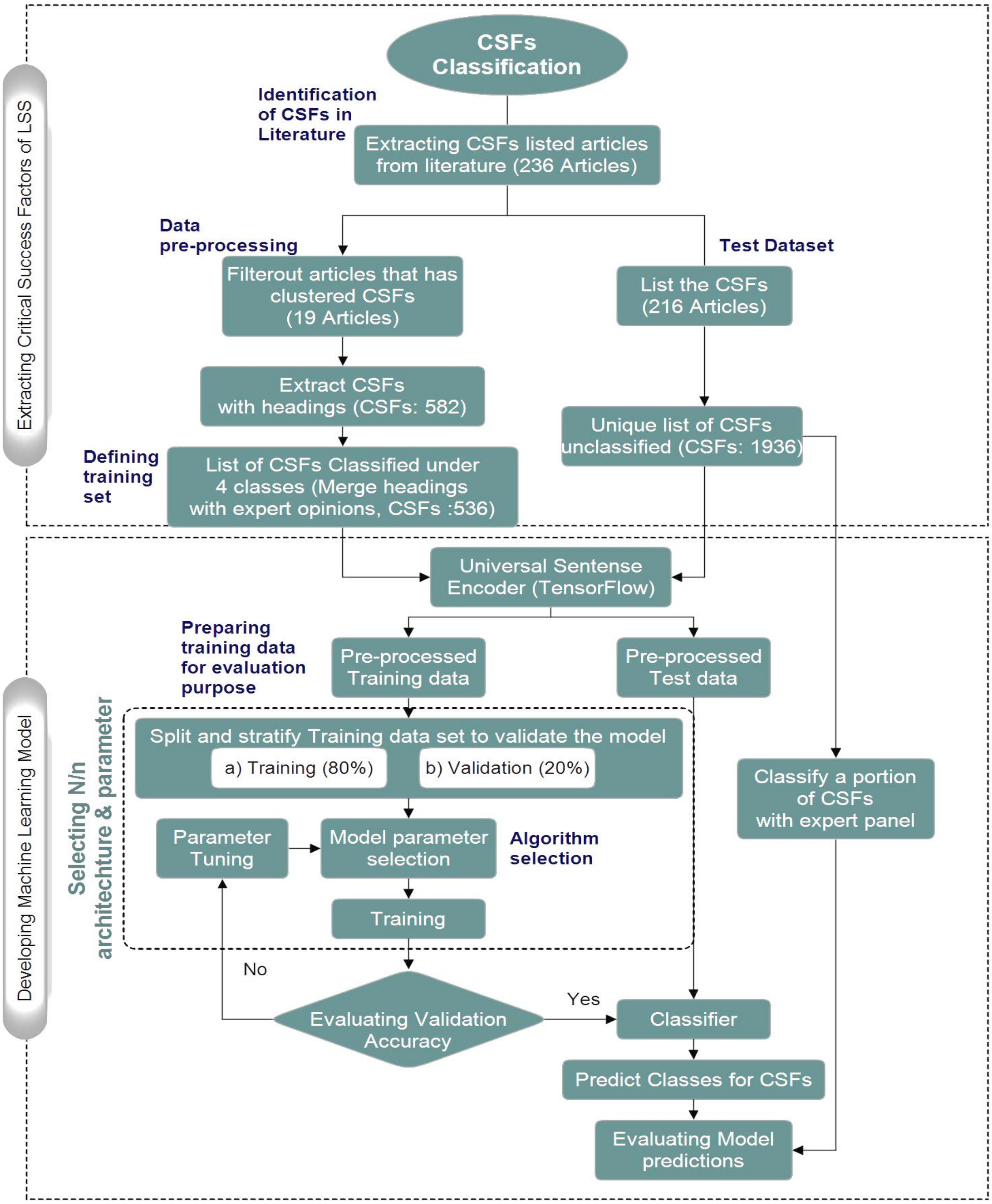


**Figure 3.3 The methodology of classifier development**

The downside of focusing on the many CSFs prescribed in the literature is the difficulty in developing a coherent theory — for example, Hilton & Sohal, (2012) mention 23 CSFs under five headings; and Cherrafi et al. (2017) mention 9 CSFs. Also, literature analysis on CSFs revealed that prior studies related to CSFs in LSS suffer from two deficiencies. Firstly, although 3318 CSFs (from 216 articles) have been extracted from literature, only 582 (from 19 articles) have been classified into manageable headings by the respective authors (Table 3.3). Secondly, prior studies seem to have used ad hoc methods to classify and verify their results using different methods. None of the studies provide a method of classifying or predicting the class for the rest of the CSFs available in the literature. This issue was addressed using word embedding in NLP, a form of ML (Sharp et al., 2018) to organise 3318 CSFs into four manageable and meaningful themes: Leadership Engagement, LSS Culture, LSS Initiation, and LSS Execution. Thus, the objective of consolidating CSFs is to harness large volumes of LSS literature on CSFs and classify them via ML to support the development of a theoretical model that explains how LSS project implementation achieves quality performance, customer satisfaction and business results.

**Table 3.3 The 19 articles that have been classified into headings.**

| Subject area | Citation | Focus Industry | The method used to classify | Themes |
|---|---|---|---|---|
| SS | Talankar et al. (2015) | Manufacturing | Interpretive Structural Modelling (ISM) | 11 |
| Lean | Noori (2015) | Healthcare | Focused group discussion | 5 |
| SS | Mehrjerdi (2011) | Manufacturing | Based on literature | 3 |
| SS | Marzagão& Carvalho (2016) | Manufacturing | Ad-hoc (validated through Partial least square) | 3 |
| Lean | Kumar et al. (2019) | Manufacturing | Fuzzy Logic | 5 |
| TQM | (Hietschold et al., 2014) | General | Focused group discussion | 6 |
| Lean | Costa et al. (2019) | Manufacturing | Decision-Making Trial and Evaluation Laboratory (DEMATEL) analysis | 11 |
| Lean | Belhadi et al. (2019) | Manufacturing (SMEs) | Analytical Hierarchy Process (AHP) | 5 |
| CI | Sunder & Prashar (2020) | Manufacturing | Classified with ranking (Verified through Principal component analysis) | 6 |
| CI | Gonzalez Aleu& Van Aken (2016) | General comparison | Authors preference | 4 |
| LSS | Parmar& Desai (2020) | Manufacturing | Discussion with experts (Validated through fuzzy DEMATEL) | 5 |
| LSS | Abu Bakar et al. (2015) | General | Affinity Diagram process | 9 |
| LSS | Habidin & Yusof (2013) | Manufacturing | Ad-hoc (validated through Structural Equation Modelling) | 7 |
| LSS | Hilton& Sohal (2012) | General | Fieldwork/ expert interviews | 5 |
| LSS | Mustapha et al. (2018) | General | Authors preference (validated through multiple-case study) | 9 |
| LSS | Pandey et al. (2018) | Manufacturing | Analytical Hierarchy Process (AHP) | 4 |
| LSS | Raval et al. (2018a) | General | fuzzy MICMAC analysis | 5 |
| LSS | Sreedharan et al. (2019) | General | Fuzzy Logic | 4 |
| LSS | Yadav & Desai (2017b) | General | fuzzy AHP | 5 |

Notes:
SS- Six Sigma, CI- Continuous Improvement, LSS- Lean Six sigma
M- Manufacturing, H-Healthcare, G-General

### 3.4.2 Extracting Critical Success Factors of LSS

Extraction of CSFs is essential to design the classifier model using ML. The researcher performed a literature review on CSFs for Lean, SS, TQM and CI implementation in both the manufacturing and service sectors. The literature review was carried out in the EBSCO, ELSEVIER, EMERALD, IEEE, SCOPUS, and SPRINGER databases. The inclusion criteria were journal-publications from the year 2000 to present and publications that address CSFs in the areas of manufacturing and the service industry. The search included keywords such as ‘‘Critical success factors’’ OR ‘‘Success factors’’ OR ‘‘Enablers’’ AND ‘‘Lean Six sigma’’ OR ‘‘Lean Sigma’’ OR ‘‘Lean’’ OR ‘‘Six sigma’’ OR ‘‘LSS’’ OR ‘‘TQM’’ OR ‘‘Continuous Improvement’’. Finally, 287 articles were selected for review, and, after manual filtering, 235 articles were selected that have listed CSFs. Among the final reviewed articles, 52% represented the CSFs in the Manufacturing industry, 14% were discussing the CSFs generally (both manufacturing and service) and another 14% listed the CSFs of Small and medium enterprises (SMEs). The rest represented the CSFs of other industries such as IT, Aerospace, Construction, Education and Healthcare.

### 3.4.3 Deep Learning

Artificial intelligence (AI) is a general term that refers to techniques that teach machines to do things that come naturally to humans. One such AI technique is ML, which is a set of algorithms trained on data to make decisions similar to humans. Furthermore, in ML, DL is a biological structure-inspired algorithm that mimics functions like the brain's neural structure for creating intelligent machines and systems (Aydoğan & Karci, 2020; Liu & Wang, 2020). A typical supervised deep learning model consists of an input layer, which takes labelled raw data in tensor form (sometimes these could be features extracted from raw data), then works together with some hidden layers and activation functions that process input data to learn different patterns in it. Lastly, the output layer gives categorical (for classification) or real number outputs (for regression tasks). Typically, a supervised learning model is trained on a large set of data until the difference between the output layer prediction and label of input difference is minimal. For this purpose, each deep learning model is equipped with an optimisation algorithm and a loss function. DL techniques have evolved through the decades and their application has now spread not only to computer vision and autonomous vehicles but also to NLP (Aydoğan & Karci, 2020; Goodfellow et al., 2014; Wang et al., 2016; Zhang et al., 2019). Text classification remains a major theme in NLP, with a wide range of real-world applications in information retrieval due to its major implications (Gargiulo et al., 2019). To classify text with DL models requires input text transformed into numeric tensors. This is done by segmenting texts into tokens (words, characters etc.) and then by associating numeric vectors. There are multiple ways to vectorise or to tokenise a text. Two major ways are one-hot encoding and word embedding.

One-hot encoding uses a vocabulary index to uniquely represent a word (Chen et al., 2018; Pham & Le, 2018). One-hot encoded vectors are binary, sparse, and highly dimensional (equal to the length of vocabulary). In addition, one-hot encoding does not capture the context of a word in text, nor its semantic and syntactic similarity and relationship with other words in the text. For example, `similar' and `same' are related, but one-hot encoding won't capture the semantic relationship between them. Word embedding is a popular technique that has overcome the shortcomings mentioned above. Word embedding maps a word to a vector of real numbers (Hinton & Ghahramani, 1997). This mapping is not manual; in fact, the model is trained to learn weights for embedding space that project each word into vector space (Figure 3.4). There are many popular word embedding methods, and Word2Vec and GloVe are prevalent among them (Liu & Wang, 2020; Neelakantan et al., 2014; Pennington et al., 2014).

| | 1 | 2 | 3 | • • • • • • • • • | n |
|---|---|---|---|---|---|
| Top | 1 | 0 | 0 | • • • • • • • • • | 0 |
| management | 0 | 1 | 0 | • • • • • • • • • | 0 |
| involvement | 0 | 0 | 1 | • • • • • • • • • | 0 |
| • • • • • Vision | | | | • • • • • • • • • | |
| plan | 0 | 0 | 0 | • • • • • • • • • | 0 |
| statement | 0 | 0 | 0 | • • • • • • • • • | 1 |

**Figure 3.4: Example for one hot vector**

While there is consensus that word embedding captures the semantic information of words, with regard to a full sentence it fails to capture the relationship among multiple words and phrases in the same sentence (Conneau et al., 2017). When working with textual data in NLP, for tasks which require the meaning of a sentence, it is essential to consider embedding sentences or phrases. To address this, Conneau et al. (2017) and Cer et al. (2018) proposed sentence level embedding. This allows representing the whole sentence in vector form rather than combining word embedding of each word in the sentence (Cer et al., 2018; Conneau et al., 2017). In our study, CSFs are like phrases where groups of words together make sense. Therefore, this study focuses on the using sentence embedding to vectorise CSFs for DL models.

### 3.4.4 Deep Neural Network for Classification

Generally, Multi-class classification can be formulated as follows: $\mathrm{X} \subset \mathbb{R}^{\mathrm{D}}$ is a set of M instances, each of which is a *D*-dimensional feature vector, and C is a set of labels or classes (Limberg et al., 2020; Nam et al., 2014). Each *X* instance is associated with a subclass of *C*, known as the relevant class, where all other labels are irrelevant. The training model must learn a mapping function $f : \mathbb{R}^{\mathrm{D}} \rightarrow 2^{\mathrm{C}}$ that assigns a subset of class to a given X instance in order to build a classifier. For this type of classification problem, many algorithms have been developed in the past, such as the binary significance algorithm, pairwise decomposition, and label power-set. However, in our case Deep Neural Networks (DNN) scale well and function effectively by learning features from raw inputs that are typically smaller than hand-crafted features derived from raw inputs. Developing a CSF classifier is not only encompassing ML which is a subset of AI but, it is also a combination of the state-of-the-art technique NLP and subsets such as Word Embedding, Neural Network (NN) and supervised Machine Learning (SML).

To develop this multi-class classifier, where the single classification label belongs to a set with more than two elements, it is essential to use frequencies of words and context data to preserve the meanings of word embedding to encode semantic significance in a word embedding (Gargiulo et al., 2019; Naili et al., 2017). This study has employed TensorFlow, a Google-released open-source numerical computing framework specifically designed to ease tedious sentence embedding for the implementation of NN (Cer et al., 2018). TensorFlow is primarily designed for creating deep NNs and it offers integrated features, such as activation, stochastic optimisation techniques and convolutions for the implementation of deep learning algorithms (Bengfort et al., 2016; Cer et al., 2018; Ganegedara, 2018).

***Data-Set Description***

To train the DL classifier, the researcher used the CSFs (from 19 articles) that were already grouped under various headings as the training data. In collaboration with an expert panel of four, the researcher was able to merge several headings into four headings (Leadership Engagement; LSS Culture; LSS Project Initiation; LSS Execution). An example of the headings merged to create the first class of Leadership Engagement is provided in Table 3.4.

**Table 3.4 Merged headings to create the class: Leadership Engagement**

| | **Sub-Heading** | **Critical Success Factor (CSF)** |
|---|---|---|
| **Heading 1: Leadership Engagement** | Process ownership | Top management commitment |
| | Human resource management | technical support; empowerment of people |
| | Strategic Factors | Support and commitment of Top management |
| | Strategic orientation | Shared vision and clear sense to lean outcomes |
| | Management practices | Management involvement, responsibility, and commitment |
| | executive engagement | management must be visible and show consistent support |
| | Management responsibility | Management involvement, support, and commitment |
| | Management Leadership | Commitment of the management |
| | Managerial | Decentralised decision-making |
| | Organisational | Bottom-up vs Top-down approach |
| | Readiness for CI deployment | leadership for CI deployment |
| | CI delivery and lessons learned | reward and recognition by top management |
| | Organisation | Management involvement |
| | Management commitment and leadership | Strong top management involvement and commitment |
| | Leadership | Responsibility |
| | Structured improvement procedures | Managing improvement, decision making in planning process |
| | Focus on metric | communication on goals |
| | Factors relating to leadership | An organisation that supports Leadership |
| | Organisational infrastructure | Strategic direction and alignment |
| | Management commitment and involvement | Support and commitment of top management |
| | Management commitment and involvement | Funds allocation |
| | Strategic based LSSEs | Top-management commitment, involvement, and support |
| | Management commitment and leadership | Leadership |

To create the training set, the researcher removed duplicate CSFs and selected only 536 unique ones with their headings. Most CSFs examined in the literature are phrases of varying lengths. As a result, a universal sentence embedder from the TensorFlow hub was implemented, known as the universal sentence encoder (Cer et al., 2018). Further, to ensure that all words were lowercase prior to encoding, each CSF was pre-processed. There are two advantages to using the universal sentence encoder: first, it converts single words or sentences into fixed-length vectors, which can be used to convert multiple CSFs into one. Second, it also prevents padding short vectors with zeros. Since the universal encoder has been trained on a large corpus of data, it is better suited to learning with limited training data (Chen et al., 2018; Chen, 2018). During the embedding process, the training data were shuffled, and the headings mapped from 1 to 4. For evaluation purposes, the training data set (536) was split into two parts: a training set (80%) and cross-validation set (20%). Due to the inconsistent nature of the training data, stratification sampling was utilised to minimise biases in both sets of data.

***Model Architecture***

NN classification process is illustrated in Figure 3.5. The diagram shows a five-layer model with an input layer of 512 nodes (equal to the length of the vectored CSFs), an output layer of 4 nodes (corresponding to the number of classes), and three hidden layers of (128, 64, 64) nodes (see model parameters in Table 3.5).

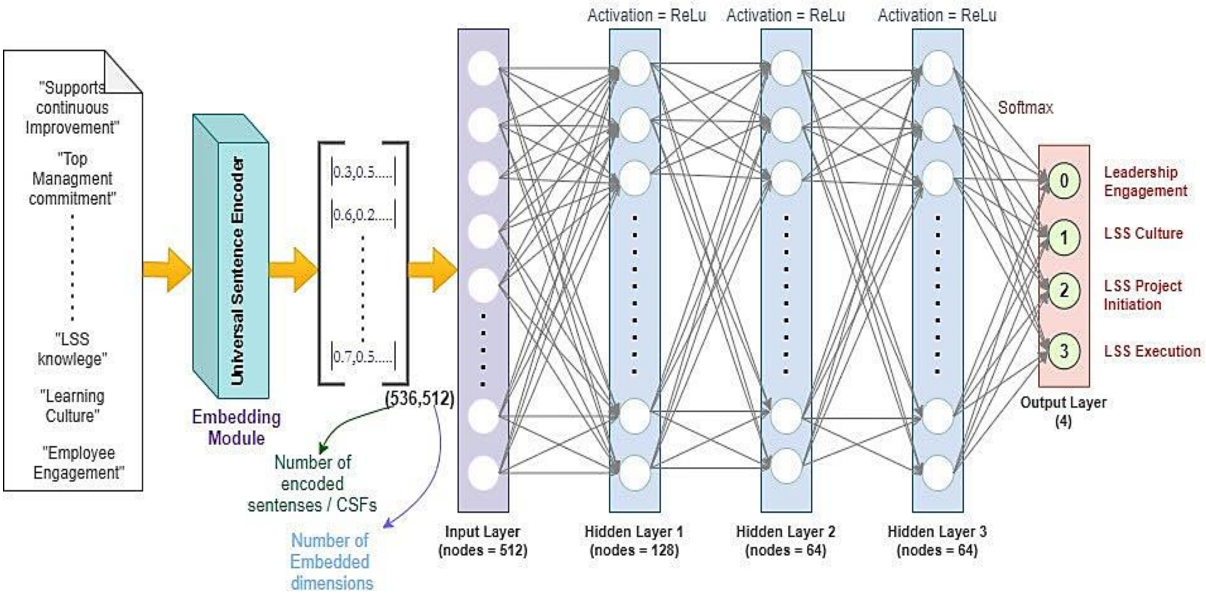


**Figure 3.5 Neural network for classifier model**

**Table 3.5 Model parameters**

| Model Parameter | | Value |
|---|---|---|
| Hidden Layer 1 | Number of nodes | 128 |
| | Activation function | ReLu |
| | L2 regularisation | 0.01 |
| | Dropout probability | 0.7 |
| Hidden Layer 2 | Number of nodes | 64 |
| | Activation function | ReLu |
| | L2 regularisation | 0.0001 |
| | Dropout probability | 0.5 |
| Hidden Layer 3 | Number of nodes | 64 |
| | Activation function | ReLu |
| | L2 regularisation | 0.0001 |
| | Dropout probability | 0.5 |
| Output Layer | Number of nodes | 4 |
| | Activation function | SoftMax |
| Optimiser | | rmspop |
| epochs | | 70 |
| Split | | 20% |
| Batch size | | 100 |

The input layer is the first layer of the neural network, and it contains the information required for processing by subsequent layers. The classification system also includes a sentence embedding module that has been pre-trained on a large data corpus. It converts input CSFs into a multi-dimensional (R512) vector representation for the next layer in the neural network. For the hidden layers the researcher employed the Rectified Linear units (ReLu) activation function f (x)= max (0, x). The dense output layer was activated before loss computation with the 'SoftMax' activation parameter, which is the most general in this form of text classification task (Castaneda et al., 2019; Limberg et al., 2020; Nam et al., 2014). SoftMax is a function that condenses a vector into the range of real numbers (0, 1), and all the results (probabilities) add up to 1 (Ho & Wookey, 2020; Ruby, 2020). Considering samples Si = (i = 1, 2, 3, …. n) in the training data then the SoftMax function for the given classes in C can be calculated using following equation:

$$\boldsymbol{f(S)_i = \frac{e^{S_i}}{\sum_j^C e^{S_j}}} \tag{3-1}$$

Where Sj are the scores inferred from the total of each class in C and therefore the SoftMax activation for a class Si depends on all the scores in S. For optimising the performance of a neural network, the cost function is critical for determining the weights of the NN (Ho & Wookey, 2020). After the activation function, a binary cross-entropy (BCE) has been used as the loss function. BCE transforms the smoothed output from the SoftMax function with probabilities while penalising any deviation from the target label. The formulation for BCE can be defined as follows:

$$\boldsymbol{L} = \sum_{i=1}^{2} .\, \boldsymbol{t_i} \log \boldsymbol{P_i} = [\boldsymbol{t_i} \log(\boldsymbol{P_i}) + (\mathbf{1} - \boldsymbol{t_i}) \log(\mathbf{1} - \boldsymbol{P_i})] \tag{3-2}$$

where, $t_i$ is the truth value or the target label taking a value between 0 or 1 and $P_i$ is the probability assigned from SoftMax function for the $i^{th}$ class. BCE is often considered to be the average of all data samples. Therefore, for N data points equation (3-3) is given as shown:

$$\boldsymbol{L} = \frac{\mathbf{1}}{\boldsymbol{N}} \sum_{i=1}^{N} .\, \boldsymbol{t_i} \log(\boldsymbol{P_i}) + (\mathbf{1} - \boldsymbol{t_i}) \log(\mathbf{1} - \boldsymbol{P_i}) \tag{3-3}$$

To train a neural network, as in Figure 3.5, from a set X of N training instances, three steps are performed in the training stage: network initialisation, parameter learning, and output activation. As shown in Table 3.5, the L2 regularisation is implemented in hidden layers and dropouts are included after each hidden layer to avoid overfitting.

***Implementation Details***

For the implementation of this ML model the researcher employed TensorFlow with Keras API (Bengfort et al., 2016; Chen, 2018; Ganegedara, 2018). Networks were trained with 100 training trials per batch for at most 70 epochs with early stopping based on the classifier loss on the validation set. Specifically, if the validation loss for class prediction did not improve (i.e., reach a new lowest value) for 10 epochs, training was stopped and the model which resulted in the lowest validation loss was saved. Parameter updates were performed once per batch with the ‘‘rmsprop’’ to optimise the model. This summarises the selection of parameters for the model.

***Evaluating Classifier Model***

In order to evaluate the performance of the proposed method, accuracy, precision, recall and F1-scores were chosen as the major evaluation metrics (Ferdinandy et al., 2020; Lakhal et al., 2018; Zhang et al., 2019), which are defined as follows:

$$Precision = \frac{TP}{(TP + FP)} \quad (3\text{-}4)$$

$$Recall = \frac{TP}{(TP + FN)} \quad (3\text{-}5)$$

$$F_1Score = \frac{2 * Precision * Recall}{(Precision + Recall)} \quad (3\text{-}6)$$

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP - FN)} \quad (3\text{-}7)$$

where TP, TN, FP and FN are the true positives, true negatives, false positives, and false negatives, respectively. Precision, and Recall are expedient measures of success of prediction when the classes are very imbalanced. In information retrieval, precision is a measure of result relevancy, while recall is a measure of how many truly relevant results are returned. The F1-score is the average of precision and recall (Aydoğan & Karci, 2020; Pham & Le, 2018).

Through repeated re-sampling, cross-validation allows models to be tested using the entire training set, maximising the total number of points used for testing and possibly to reduce the chance of over-fitting (Rao et al., 2008). In this classification model the researcher used 20% of the training data with designated classes as the cross-validation data set. Since, there are imbalanced data for each class in the classified CSFs, the data was stratified before splitting the training set to limit the bias that can occur.

Table 3.6, exemplifies the evaluation criteria of the classifier predictions. According to the table within the cross validation (CSV) set, 82.2% of the classification predictions are accurate. This level of accuracy is acceptable for the theoretical model development purpose. The accuracy of the training model and the cross-validation model as well as the loss curves for both are depicted in Figure 3.6.

**Table 3.6 Evaluation metrics for cross validation**

| | Precision | Recall | $F_1$ Score |
|---|---|---|---|
| Leadership Engagement | 0.684 | 0.867 | 0.765 |
| LSS Culture | 0.902 | 0.881 | 0.892 |
| LSS project Initiation | 0.818 | 0.871 | 0.844 |
| LSS project Execution | 0.786 | 0.579 | 0.667 |
| | | | |
| Accuracy | | | 0.822 |
| Macro average | 0.798 | 0.799 | 0.792 |
| Weighted average | 0.827 | 0.822 | 0.820 |

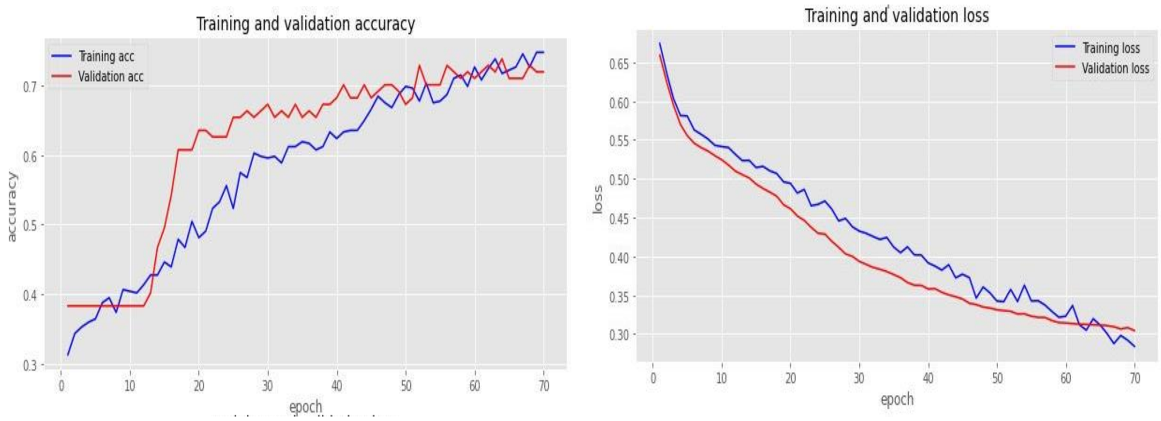

**Figure 3.6  Accuracy and loss of training and cross validation data**

The test data represents the 1936 CSFs extracted from literature that have not been classified. With the classifier model the researcher generated predictions for these unclassified CSFs. For further validation and to assess the performance of this classifier the researcher employed an expert panel of four to classify a portion of test data under the four headings. To evaluate the predictions, the researcher first provided the experts the classification used for training the model as shown in Figure 3.7.

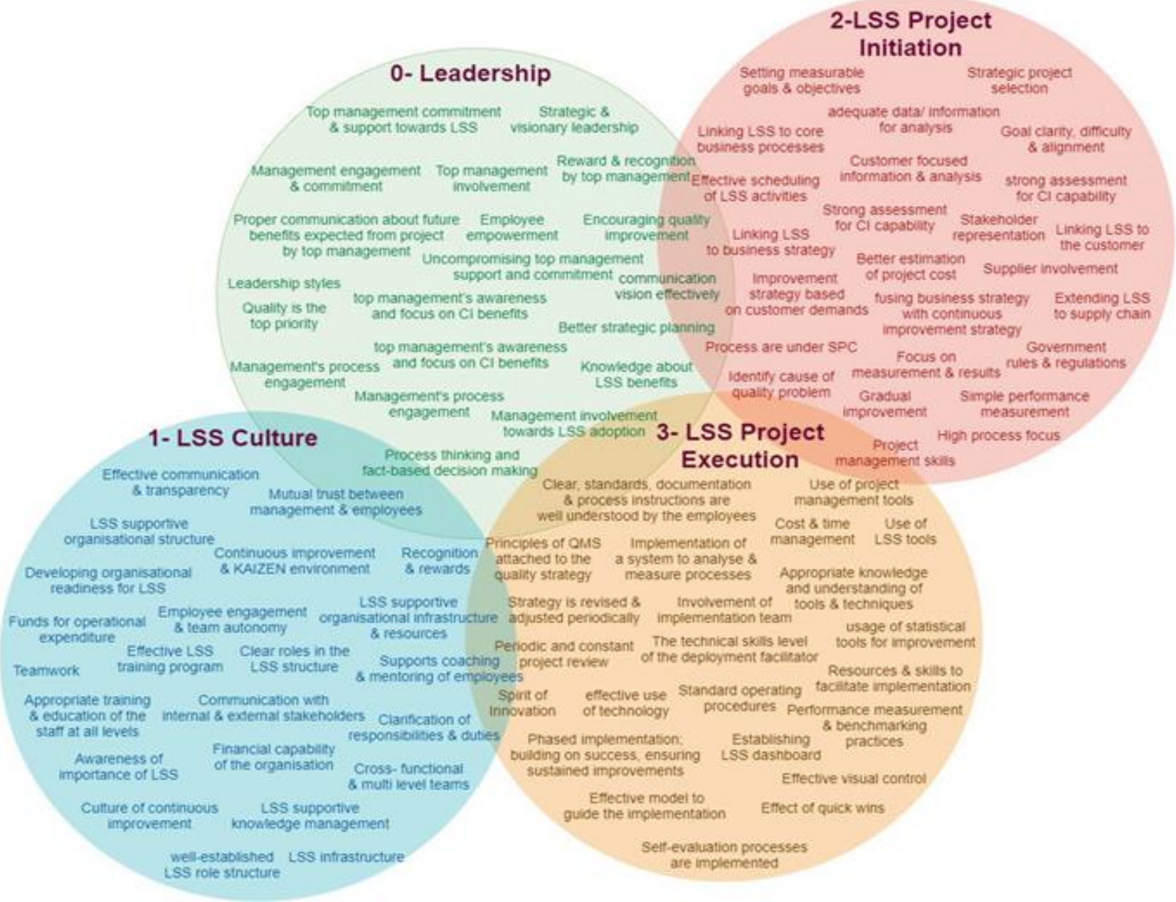

**Figure 3.7  Graphical representation of training data**

To evaluate the results of the expert panel assessment the metric root mean square error (RMSE) was used, which provides an indication regarding the dispersion, or the variability of the prediction accuracy as shown in equation (3-8).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}} \quad \textbf{(3-8)}$$

Based on the five-point Likert scale, RMSE = 0.78. Since both ‘‘strongly agree’’ and ‘‘agree’’ indicate a valid prediction, the researcher recalculated the RMSE value using a three-point Likert scale. In particular, the three-point Likert scale generated an RMSE of 0.26, indicating that the prediction model is accurate. Importantly, this measure confirms that the manual classification can be relied on as ground truth to evaluate the ML model. The histogram of how the experts responded to the prediction (Figure 3.8) reveals that the results are left skewed as the ‘‘strongly agree’’ response is targeted for each prediction.

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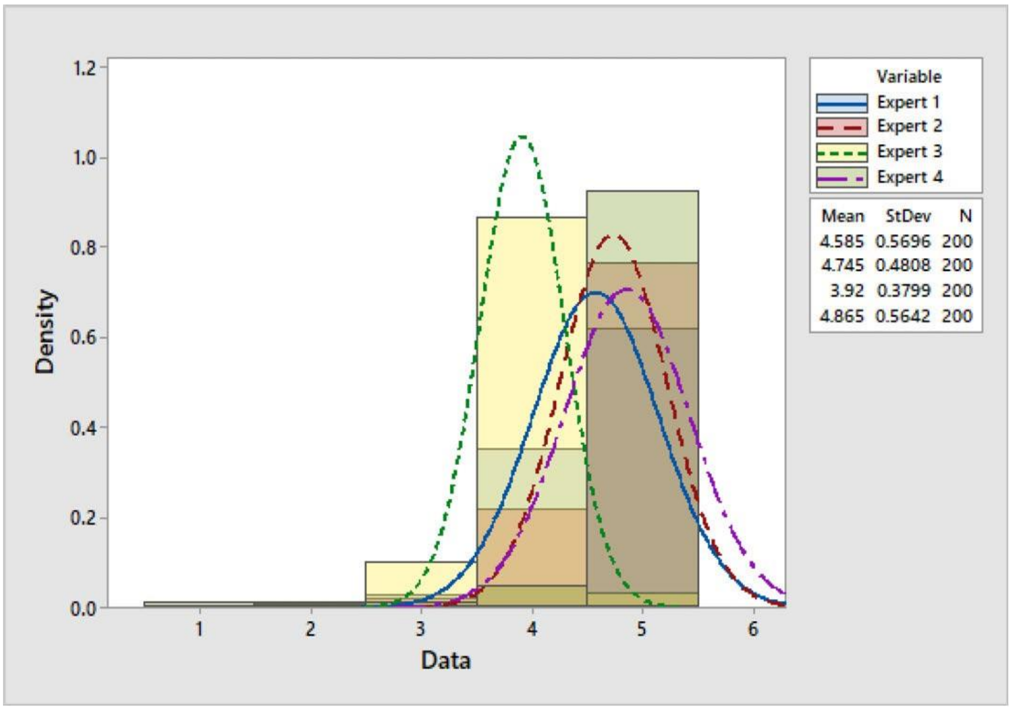


**Figure 3.8 Histogram of expert panel results**

A DL model was tested against the predication of the manually classified data to evaluate its performance according to the evaluation criteria. Table 3.7 depicts the evaluation metrics of test data. To test model predictions, the model was executed with 100 epochs and a batch size of 10. Testing accuracy was calculated to be 95.95%. Precision, recall and F1-scores are shown in the Table 3.7.

**Table 3.7 Evaluation metrics for test data**

| | Precision | Recall | $F_1$ Score | Support |
|---|---|---|---|---|
| Leadership Engagement | 0.978 | | | 282 |
| LSS Culture | 0.992 | | | 812 |
| LSS project Initiation | 0.943 | | | 574 |
| LSS project Execution | 0.889 | | | 268 |
| | | | | |
| Accuracy | | | 0.959 | 1936 |
| Macro average | 0.951 | 0.960 | 0.954 | 1936 |
| Weighted average | 0.961 | 0.959 | 0.959 | 1936 |

The CSFs in literature are sentence-based. To interpret the relationship between CSFs to each other, a higher dimensional vector space is needed because the semantic relationship between words or sentences is crucial in classification of CSFs. Principal component analysis (PCA) is a method that effectively reduces a high-dimensional vector into a lower-dimensional vector while preserving the local structure in the high-dimensional space (Figure 3.9). PCA can also provide greater insight into the vector space. After dimensional reduction using (3-9), the word vector in the test sample appears as shown in Figure 3.9. On the 3D plane, rotated PCA plots indicate at least two distinct clusters ('class 0-Leadership Engagement' and 'class 1-LSS Culture'). This factoid assures us that the Test data set (1936 CSFs) can be clustered under four themes.

$$\boldsymbol{ReducedDataset} = \boldsymbol{FeatureVector^T} \times \boldsymbol{OriginalDataset^T} \qquad \textbf{(3-9)}$$

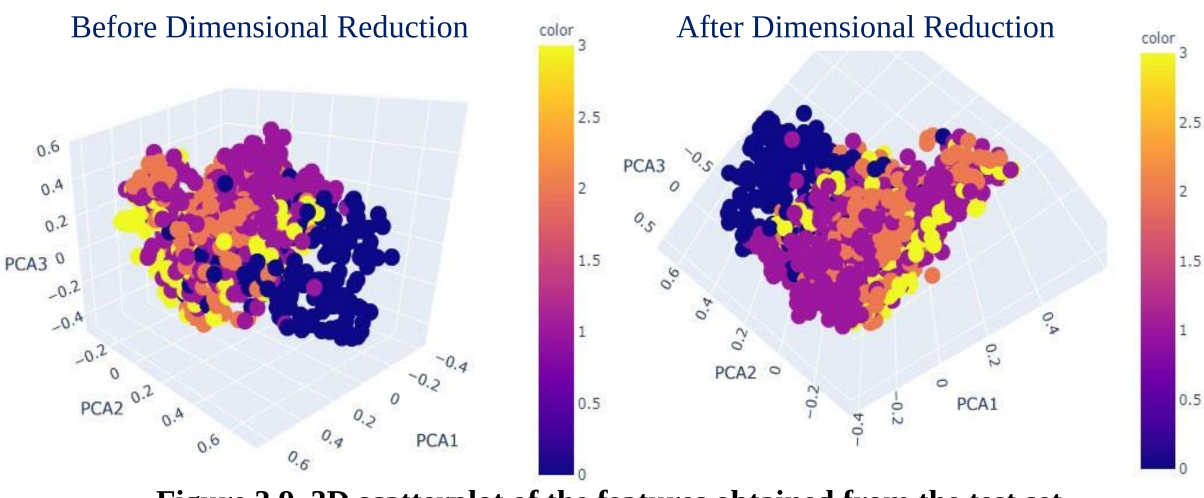


**Figure 3.9 3D scatterplot of the features obtained from the test set.**

## 3.5 Conceptual Model and Propositions

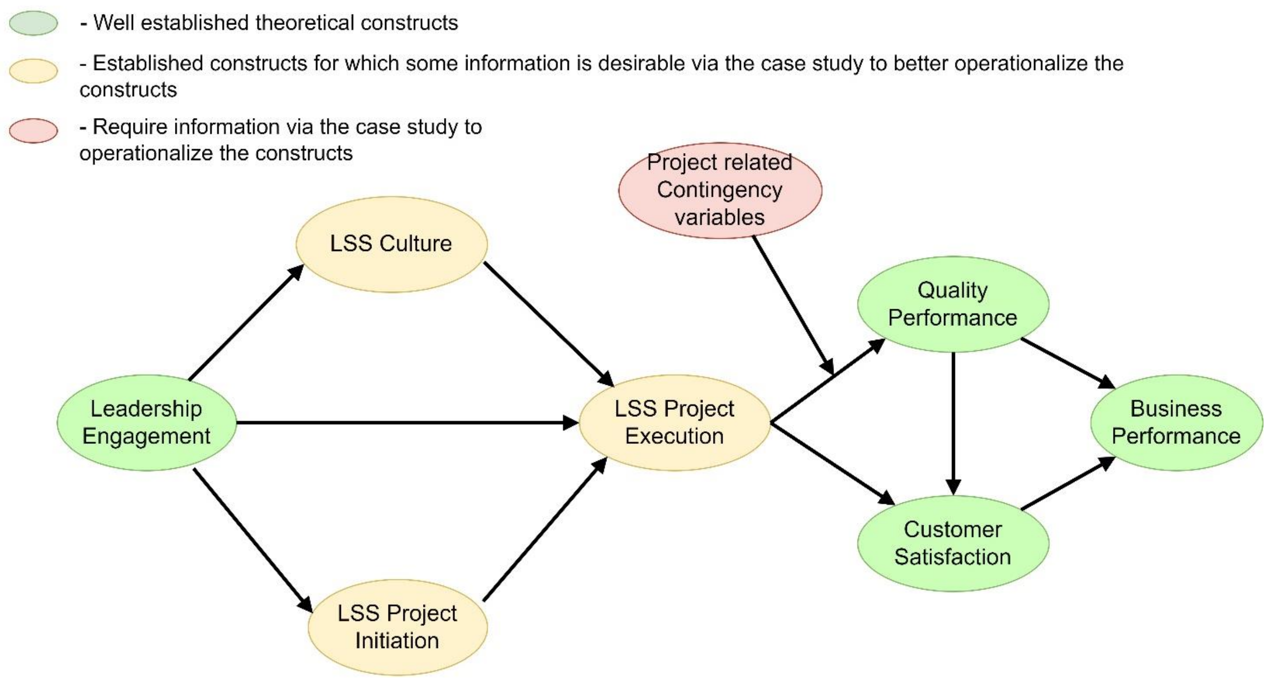


**Figure 3.10 Final conceptual model on the theoretical underpinnings of LSS**

The theoretical concepts of the final model are depicted in Figure 3.10. Table 3.8 depicts the working definitions of the concepts in the conceptual model. It is important note that the conceptual model has been derived using an LSS project lens. Papers included in Table 3.8 are the ones that attempted to either formulate or test a parsimonious theory on SS/LSS. Needless to reiterate, the analysis of the literature on CSFs through ML (section 3.4) enabled the researcher to gain a better working knowledge on constructs that are not very well covered in SS/LSS theory building/testing studies. The reader will note that the concepts shown in Table 3.8 tally well with the concepts shown in Table 3.2, which vindicates the two pathways being used to derive the final conceptual model.

## Table 3.8 Working definitions of the concepts

| Concept | Working Definition | Sources | Remarks |
|---|---|---|---|
| Leadership Engagement | Leadership engagement is a concept that signifies leadership's active involvement in defining the problem, executing, reviewing, coaching, and mentoring the team to gain more commitment from them and engaging them effectively to ensure success. | Adams-Robinson, 2021; Firouznia et al., 2021; Laureani and Antony, 2019; Sutherland et al., 2020 | Well established construct consistent with quality and highlighted in CSFs classification |
| CI Culture | CI culture is a culture where people are empowered to make improvements on an ongoing basis, valuing everybody's contribution as well as training. A CI culture facilitates communication, identification of strategies, and challenges. | Barcia et al., 2022; Cameron and Quinn, 2011; Featherall et al., 2019; Iyede et al., 2018; Zu et al., 2010 | Well established construct: the CSFs analysis provided additional support. |
| LSS Project Initiation | LSS project initiation is the process of identifying a problem or opportunity by listening to the four influential voices (customer, process, stakeholders, and business) and performing a functional analysis (feasibility/risk analysis etc.) to develop a tactical plan to implement the project. | Kloppenborg et al., 2006; Söderberg, 2020; Zhang et al., 2008 | This construct lack depth in extant models, but the analysis of CSFs provided the required insights, although fieldwork would be useful in construct operationalisation. |
| LSS Project Execution | LSS project execution involves managing people, processes, and information distribution to ensure successful project deliverables, dissecting tasks into time-bound activities, identifying constraints, and providing resources and training. | Golini et al., 2016; Hellström et al., 2016 ; Marion et al., 2016 ; Ramasamy and Yusof, 2015 | Emerged from CSFs classification and need fieldwork to get a better understanding of the concept to facilitate construct operationalisation. |
| Project-related Contingency Variables | Project residual risk refers to the risk that remains after mitigating major risks. The project residual risk increases with project complexity and uncertainty. | Benta et al., 2011; Dao et al., 2016 ; Loch et al., 2006 ; Purvis et al., 2016 | Need fieldwork to identify the indicator variables. |
| Quality Performance | Quality performance is a multifaceted construct that encompasses various dimensions, including product or service quality, process quality, and the quality of people's lives. | Lindemann et al. (2003); Schroeder et al. (2008); Sin et al. (2015); Zu et al. (2008) and many others | Well established construct (consistent with conceptual and operational definitions used in TQM). |
| Customer Satisfaction | It is the ability to satisfy both internal and external customer expectations and needs during the product or service production process. The product or service must meet the quality requirements of internal customers, who are directly involved in the production process. | Lindemann et al. (2003); Schroeder et al. (2008); Sin et al. (2015); Zu et al. (2008) and many others | Well established construct (consistent with conceptual and operational definitions used in TQM). |
| Business Performance | Business Performance refers to the results of a manufacturing or service process that are characterised by improved quality output, reduced waste, and increased reliability. Among the factors that determine a company's competitive edge and profitability are perception, customer satisfaction, operational performance, quality indices, and financial performance. | Kornfeld and Kara, 2011; Schroeder et al., 2008; Sin et al., 2015 | Well established construct (consistent with conceptual and operational definitions used in TQM). |

The model proposes a comprehensive framework for examining the relationships and influences between key factors that contribute to the successful implementation of LSS. The model suggests that effective leadership is crucial for successful LSS projects and fostering CI (Jones et al., 2010; Schroeder et al., 2008; Zu et al., 2008). Leadership engagement positively impacts LSS Project Initiation, LSS Execution, and LSS Culture (Jones et al., 2010; Krueger et al., 2014; Zu et al., 2008). Together, these propositions emphasise the critical importance of leadership involvement during all stages of the LSS lifecycle, including project initiation, execution and organisational culture resulting in improved long-term performance (Choo et al., 2015; Douglas et al., 2015; Jacobs, 2015). Thus, the first three propositions are stated as follows:

**Proposition 1:** Leadership Engagement positively influences and enhances the initiation phase of LSS projects. Specifically, organisations with strong Leadership Engagement are more likely to prioritise and initiate LSS projects effectively, aligning them with strategic goals and objectives.

**Proposition 2:** Leadership Engagement plays a significant role in driving the successful execution of LSS projects. When leadership is actively engaged in LSS initiatives, it fosters a culture of commitment and accountability that enhances the execution phase, ensuring that projects are completed efficiently and effectively.

**Proposition 3:** Leadership Engagement contributes positively to the development and sustenance of a robust LSS culture within organisations. Strong leadership support and involvement are instrumental in fostering a culture that values continuous improvement and problem-solving, aligning with the principles of LSS.

Effective initiation of LSS projects results in positive outcomes for their subsequent execution. Essentially, LSS projects that begin with a defined plan, clear objectives, and adequate resource allocation are more likely to succeed. Thus, as highlighted by Schroeder et al. (2008) and Zu et al. (2008) a thorough and comprehensive project initiation phase sets the stage for achieving desired outcomes. Having a clear roadmap, adequate resources, and a shared understanding of goals increases the likelihood of success. The importance of project initiation as a crucial step in the LSS journey is stressed in the fourth proposition; in lay language the proposition means that a strong start is needed to successfully execute the downstream activities to achieve (project) success. Thus, the fourth proposition is stated as follows:

**Proposition 4:** Effective initiation of LSS projects positively influences their subsequent execution. When LSS projects are initiated with clarity, well-defined goals, and adequate resource allocation, they are more likely to be executed successfully, delivering desired outcomes.

In the proposed model, the importance of a conducive LSS culture is highlighted as an important element in influencing the implementation phase of LSS projects (Kowang et al., 2016). Organisations with a robust LSS culture, where employees are well-acquainted with LSS methodologies and embrace a CI mindset, are more likely to execute projects efficiently. In this culture, employees are actively engaged in the project execution process, resulting in smoother processes and improved outcomes (E. V. Gijo et al., 2018; Lertwattanapongchai & William Swierczek, 2014). Within the LSS framework, existing research indicates that organisational culture has a profound influence on project success (Jacobs, 2015b; Zu et al., 2008). Thus, the fifth proposition is stated as follows:

**Proposition 5:** An LSS culture positively impacts the execution phase of LSS projects. Organisations with a strong LSS culture are more likely to execute projects efficiently, as employees are well-versed in LSS methodologies, fostering a continuous improvement mindset.

Efforts to execute LSS projects effectively have been shown to have a positive correlation with quality performance and customer satisfaction (Zhang et al., 2008). Most organisations that successfully execute LSS projects typically achieve significant improvements in the quality of their products and services, as these initiatives are intended to address the underlying causes of defects and inefficiencies (Schroeder et al., 2005). The result is often a higher level of customer satisfaction as a result of improved product quality and service delivery (Garvin, 1984; Prajogo & Brown, 2018). It is important to note, however, that this relationship is not always straightforward, as project-related contingency variables can introduce constraints to moderate the effects. These external factors, which may vary from one context to another, have the potential to influence how LSS project execution impacts quality performance and customer satisfaction, and therefore require further investigation and contextual analysis through fieldwork and empirical research to determine their impacts. Thus, the next four propositions are stated as follows:

**Proposition 6:** Project-related contingency variables introduce constraints in the relationship between LSS project execution and quality performance. These variables, which need further exploration through fieldwork, are likely to moderate the impact of execution on quality performance.

**Proposition 7:** Effective LSS project execution positively influences quality performance. Organisations that execute LSS projects well are expected to see improvements in product and service quality, as they address root causes of defects and inefficiencies.

**Proposition 8:** Successful LSS project execution contributes positively to customer satisfaction. Well-executed LSS projects often lead to improved processes and products, which in turn enhance customer satisfaction.

**Proposition 9**: High-quality performance positively affects customer satisfaction. Organisations that consistently deliver high-quality products or services are more likely to have satisfied customers who perceive value in their offerings.

The improvement of quality performance can lead to cost savings, increased customer loyalty, enhanced market reputation, and improved overall business results for organisations. The combination of these factors contributes to a robust business performance, thereby making the company more competitive and sustainable. Moreover, customer satisfaction improves business performance significantly (Vinodh & Joy, 2012; Zu et al., 2008). Customer satisfaction increases loyalty, repeat business, and advocates, recommending the organisation to others. Organisations gain better business performance due to increased customer satisfaction, which boosts sales, customer retention, and market share. In studies, customer satisfaction and quality performance are correlated These interconnected variables contribute to overall organisational success (Shokri et al., 2016; Sin et al., 2015; Vallejo et al., 2020). Thus, the last two propositions are stated as follows:

**Proposition 10**: Quality performance has a positive impact on overall business performance. Improved quality often leads to cost savings, increased customer loyalty, and enhanced market reputation, all of which contribute to better business performance.

**Proposition 11**: Higher levels of customer satisfaction positively influence overall business performance. Satisfied customers are more likely to remain loyal, make repeat purchases, and recommend the organisation to others, ultimately leading to improved business performance.

### 3.5.1 Model Boundaries

A model is a representation of a theory and not the theory (Cooper & Schindler, 2014; Wunsch, 1994). However, because the distinction between a theory and a model is often blurred (Busse et al., 2017), in this thesis the researcher will use the phrase "model boundaries" to mean boundary conditions (BCs) of the researcher's theory. Once the final conceptual model has been elevated to a testable theoretical model (Chapter 6), it becomes necessary to specify the BCs of the theoretical model (Busse et al., 2017; Whetten, 1989). Whereas a theoretical model specifies *what* constructs constitute the model (the building blocks) and *how* the constructs are related to one another in a cause-predictive sense, the BCs of the model refer to "who, where, when" (people, geography, and time) of the propositions to impose generalisability limitations.

The primary BC of the researcher's model is its applicability at the project level, specifically for LSS projects, rather than at the organisational level. This model/theory explains why some LSS projects may fail within and between organisations and guides organisations on improving suboptimal LSS project outcomes. However, it does not address broader organisational failures, as LSS projects alone may not rescue failing organisations. Should the leader engage more in LSS projects to save the organisation? The short answer is "probably not". Organisations may fail for number of reasons and implementing LSS projects will not save the organisation if it is not doing other things right (e.g., selecting the right product/service markets to compete with/in, anticipate changes in the environment, and implement requisite innovations). If the organisations do these other things right and select LSS as an operational strategy, then yes, the organisation is expected to perform well. Considering this BC, selecting business results as the outcome of Leadership Engagement (in LSS projects) does not seem right. The reader will note that in the final theoretical model (the one that was tested), business results do not appear as a construct.

The researcher's model/theory specifies that not all projects labelled as LSS by an organisation fall within its scope. To be included, a project must have the potential to yield a certain threshold return on investment for the leadership to engage in the quality improvement project. For example, a project aimed at reducing patients' length of stay in a hospital qualifies as LSS project due to cost reduction and (increased) customer satisfaction potential. In contrast, projects like improving hospital aesthetics might not qualify if they don't yield high returns. Thus, in LSS organisations LSS quality/process improvement projects and other quality improvement projects will always coexist, but the researcher's model/theory applies to the former. The reader will note that driver of the researcher's model 'Leadership Engagement' means the leaderships' engagement in LSS projects.[8]

## 3.6 Chapter Summary

This is an important chapter because it describes the systematic journey the researcher embarked on to develop the conceptual model which attempts to explain how successful implementation of LSS projects driven by Leadership Engagement results in planned outcomes. To develop a robust theoretical model, the researcher adhered to three fundamental requirements: defining theoretical constructs, identifying their relationships based on temporal dynamics, and specifying the model's generalisability boundaries (i.e., the BCs).

This preliminary phase of research involved extensive literature exploration, identification of gaps within and examination of existing models of Lean, SS and LSS setting the stage for systematic model development. A conceptual model based on the well-established "iron triangle" of project management was introduced (section 3.2), emphasising the key role that effective project planning and execution play in achieving quality, timeliness, and cost effectiveness. A parallel strategy was used to formulate a robust conceptual model by

[8] Fieldwork revealed that organisations define LSS projects in multiple ways. The empirical model seemed to have withstood to these multiple definitions, but great care was taken by the researcher to collect data from the right people who know what a LSS project is.

conducting a thorough review of existing Lean, SS, and LSS models (Section 3.3) and implementing a ML algorithm to consolidate CSFs based on relevant literature (Section 3.4). Consequently, the researcher was able to harmonise traditional literature synthesis with computer generated human like thinking and literature synthesis (more specifically, ML) to strengthen the concepts and well as the relationships between the concepts. This chapter therefore provides a systematic and rigorous approach to develop a conceptual model that can explain how LSS works at project level to achieve planned outcomes. The phrase “project level” is important because it a BC of the researcher’s theory/model. The next chapter covers the methodology of the study.

# CHAPTER 4
# RESEARCH METHODOLOGY

## 4.1 Introduction

The Methodology chapter is a critical chapter of a thesis because quite simply, the methodology outlines how the research was carried out to advance knowledge, given the research questions. The research questions are driven by the current body of knowledge on LSS as a quality improvement approach (Chapter 2). For the convenience of the reader, the research questions given in Chapter 1 (section 1.4) are repeated here:

> ***RQ1:*** What are the determinants that predict and explain how quality performance is achieved by implementing LSS?
>
> ***RQ2:*** What are the project-related risk factors that moderate LSS project success?
>
> ***RQ3:*** Does LSS fit to the nonmanufacturing sector as well as it would to the manufacturing sector?

Methodology not only provides the blueprint of the research (research design), but also the methods being used (tools and techniques) in answering the research questions, explaining why particular methods were chosen (and not others) for the study (Bryman, 2012). Valsiner (2017 p. ii) views methodology as "a system of mutually linked acts of creating knowledge where both abstract and concrete features of the research act are intricately intertwined". This definition extends the meaning of the term methodology to mean one's philosophy and rationale behind their research (general epistemology).

This chapter is organised as follows. Section 4.2 covers the most abstract aspect of research, namely, research paradigms (worldviews) with a justification of the "pragmatism paradigm" chosen by the researcher to answer her research questions. Section 4.3 covers the three basic mixed method research design platforms being used by pragmatists and selection of the suitable platform — namely, exploratory sequential design. In this design, qualitative data collection and analysis precedes the quantitative data collection and analysis because in such designs, the former informs the latter. Section 4.4 covers the qualitative data collection phase for which a hypothetic-deductive supportive case research design approach promulgated by Yin (2018) and Eisenhardt (1989) was used. Section 4.5 introduces the quantitative data collection phase for which a survey research design was used. Section 4.6 covers quantitative data analytic considerations including bias/systematic error and the method used to determine the minimum sample size. Section 4.7 covers key data analysis tools available for testing hypotheses involving directly unobservable variables (constructs, or as they are sometimes called, latent variables) and justification of the choice of the partial least squares structural equation modelling (PLS-SEM) technique. Section 4.8 covers the ethical considerations, and finally, section 4.9 wraps up the chapter highlighting key points.

## 4.2 Research Paradigms and their Constituents

A research paradigm is a way of viewing the world using the research problem/questions as a foundation to rest on (Bryman, 2012; Soysa, 2017). According to Lincoln (2013), paradigms represent large-scale initiatives that are organised, elucidated, justified, and defended in accordance with a set of fundamental beliefs or presumptions held by the researcher. There are four elements of a paradigm: the ontology; the epistemology; axiology and methodology (Lincoln, 2013).

The ontology describes the researcher's basic beliefs about the nature of reality as well as assumptions about the social world. The term epistemology is a term derived from the ancient Greek word episteme, meaning scientific knowledge (Kivunja & Kuyini, 2017). Put simply, the researcher's epistemology is their theory of knowledge (Bryman, 2012; Creswell, 2018; Jayamaha, 2008; Kivunja & Kuyini, 2017). While the researcher's epistemology stems from their ontology, both ontology and epistemology depend on the researcher's research questions (what does the researcher wants to know?). The axiology is defined as the process of arriving at good decisions through value judgements or correct choices. Methodology covers the research design, techniques and processes employed in a well-planned analysis, developed in the quest for creating knowledge. The researcher acknowledges that this widely used definition of methodology has a somewhat restricted meaning as it does not reliably distinguish methodology from methods (the concrete features of the research design). Based on this narrow definition of methodology, methodology covers data collection, participants, tools used, and type of data analysis used to understand and acquire useful knowledge (Bryman, 2012; Creswell, 1994; Jayamaha, 2008; Karlsson, 2009; Kivunja & Kuyini, 2017; Williams, 2007). Social science research has embraced the two types of competing mainstream research paradigms: positivism and interpretivism and the emerging paradigm pragmatism.

### 4.2.1 Positivism

Auguste Compte, the French sociologist, and philosopher introduced *positivism* as the combination of *rationality* and *empiricism*, where empiricism suggests that physical observation of time and space, the collection of scientific data, evaluation and interpretation of systemic information can prove anything. Also, rationalism—thesis, antithesis, and synthesis—can change both the theory and how it initially was posited in order to attain specific goals (Meredith, 1998). The ontology of positivism holds that there is truth regardless of the observer —that is, the truth is singular (same to everyone) and objective. The positivist epistemology holds that knowledge claims must be made via observable evidence by formulating and testing relationships between concepts (hypotheses), which are falsifiable (Bryman, 2012; Jayamaha, 2008). Consequently, the methodology follows a hypothetical-deductive reasoning. Consequently, positivism entertains quantitative data, large samples, as well as tools and techniques that can be used for testing of hypotheses through correlational research, experiments, and quasi-experiments (Bryman, 2012; Creswell, 1994; Jayamaha, 2008; Kivunja & Kuyini, 2017; Williams, 2007).

*Post-positivism* emerged as a variant of positivism to soften the rigid assumptions embedded in it. *Post-positivism's* ontological stance is critical realism. It assumes that reality exists independently of the observer but can only be imperfectly understood due to the complexity of social phenomena; it also acknowledges the likelihood of the researcher's convictions and values influencing what is being observed (Rehman & Alharthi, 2016; Salvador, 2016). *Post-positivism* has dualistic and objectivistic epistemology, but as mentioned above, positivistic assumptions have been altered with regard to the internal wall built to protect the objectivity, critical traditions and the critical environment (Rehman & Alharthi, 2016; Salvador, 2016).

### 4.2.2 Interpretivist and Constructivist Paradigms

Interpretivist and constructivist paradigms share the same ontology but differ in epistemology. Both take a subjective stance towards reality. This means different people can experience the same event differently depending on their experience. From an epistemological standpoint, interpretivists are interested in understanding how realities are individually experienced by their informants while constructivists are interested in understanding how informants' realities are constructed through their interactions with others (Guba & Lincoln, 2005; Schwandt, 1998). The ontological and epistemological positions taken by interpretivists and constructivists necessitates them to collect qualitative data from their informants to advance knowledge.

### 4.2.3 Pragmatism

The pragmatic approach to research emphasises the practicality and flexibility of methods and procedures so as to be able to answer specific research questions in an efficient and effective manner (Bryman, 2012; Creswell, 2018; Johnson & Onwuegbuzie, 2004; Karlsson, 2009). As part of pragmatism, the researcher is encouraged to be an active participant in the research process, as well as to be actively involved in making explicit choices during the process of conducting the research (Cronemyr et al., 2014; Kane, 2020). The experimental and adaptive aspects of the approach are valued, as well as the ability to adjust one's beliefs as circumstances change. In addition, it values the perspectives of individuals experiencing social problems, formulating actionable research questions (Choo et al., 2006; Miles & Huberman, 2014; Rodgers et al., 2019). Pragmatic approaches are particularly well suited for mixed methods research since they assist in bridging the gap between qualitative and quantitative approaches and finding solutions that are acceptable to all parties (Creswell, 2018; Miles & Huberman, 2014). Figure 4.1 represents the four competing paradigms (interpretivism and constructivism are treated as two different paradigms at epistemological level). This figure attempts to compare the key elements of the competing paradigms in summary form.

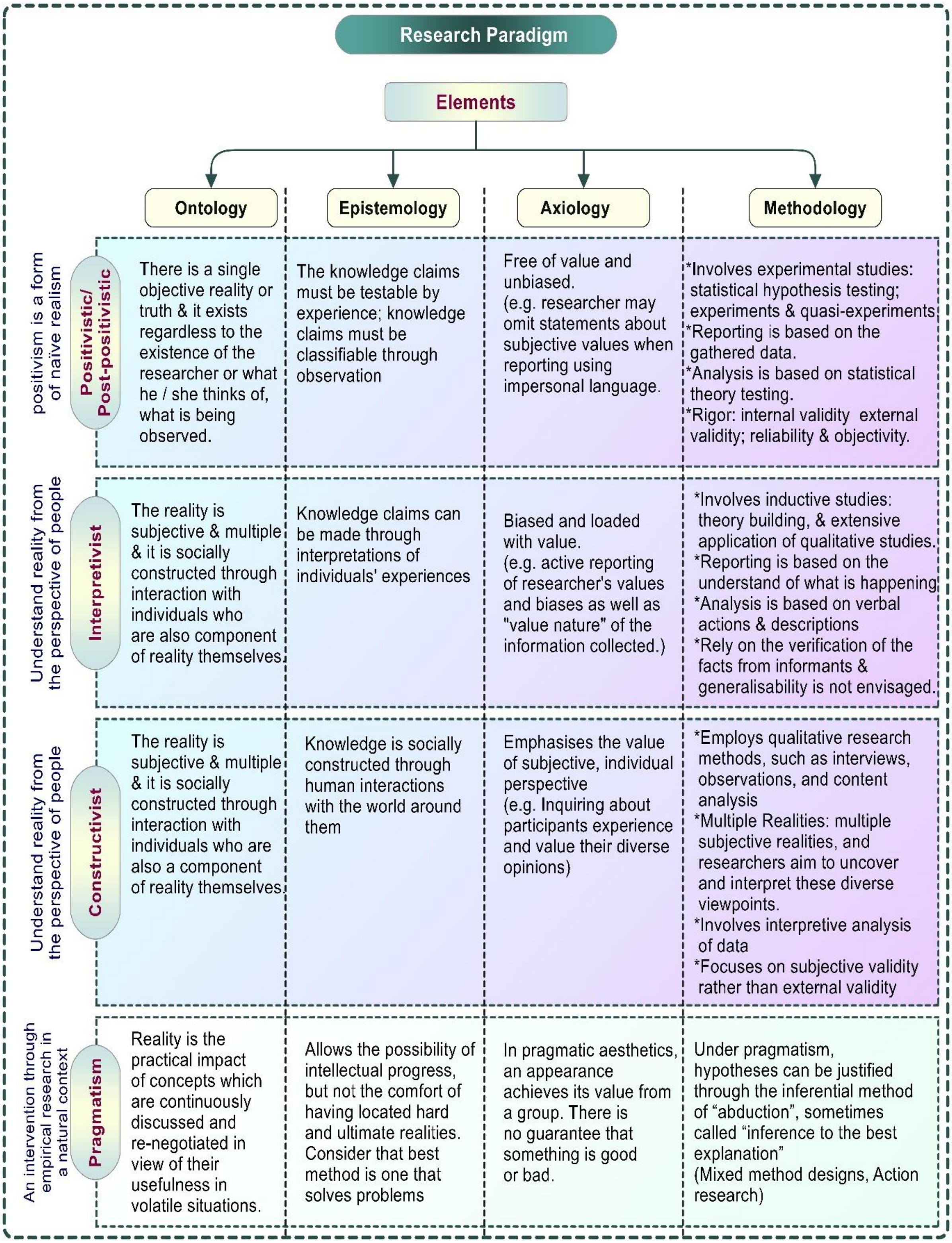


**Figure 4.1 A comparison of research paradigms (Synthesised from: Bryman, 2012; Creswell et al., 2018; Guba & Lincoln, 1994; Karlsson, 2009; Kivunja & Kuyini, 2017; Lincoln, 2013; Powell, 2001; Rehman & Alharthi, 2016; Salvador, 2016; Creswell, 2018)**

### 4.2.4 Selection of the Appropriate Research Paradigm

Research paradigm selection represents a crucial juncture in the inquiry trajectory, in which a researcher's underlying beliefs about knowledge and reality profoundly shape the inquiry. In Chapter 1, the researcher discussed the overarching objective of this study, which is to develop and empirically validate a theoretical framework describing the complex mechanisms by which LSS impacts quality performance[9]. To determine whether the proposed theoretical model is viable, the researcher has advanced a series of testable hypotheses in accordance with this objective. Along with the hypothetical-deductive approach, empirical validation of these hypotheses using statistical inference techniques also supports the positivistic/post-positivistic epistemology/methodology. The researcher's background as an engineer and an LSS expert may have subconsciously influenced the direction of research inquiries that gravitate toward a positivistic perspective.

However, the researcher acknowledges the limitations that a solely positivist approach may have, if it disregards the contextual richness that alternate paradigms, such as constructivism, contribute to social research. This study reflects a deliberate effort by the researcher to infuse the research with qualitative exploration, resulting in a case study methodology outlined by Yin (2018). Yin, like Eisenhardt (1989) stays within a post-positivist tradition but argues that when very limited prior information is available on the concepts and/or their relationships (i.e. propositions), a limited scope in-depth study on the phenomenon is need to build theory. In the researcher's study there was a need to fully understand how some of the concepts/constructs (e.g., Leadership Engagement, LSS Project Initiation, CI Culture in LSS) manifest in the practice of LSS. Without this, construct operationalisation could lead to content validity and construct validity issues. There was also a need to scope the researcher's propositions in the industry to examine whether there is a need to modify some of these in formulating the testable hypotheses, which also justifies engaging with the practitioners. According to Creswell (2018), approaches to research are influenced by philosophical worldview, research design, and research methods and are interconnected (See Figure 4.2). As a guiding principle of this research paradigm, a strategic constructive collaboration emerges between sequential research design and mixed methods approaches. Sequential design, a method that transitions from

[9] Quality performance in this study is LSS project performance because the unit of analysis of this study is an individual LSS project. Details later.

qualitative immersion to quantitative validation, represents the dynamic interaction between theory and practice.

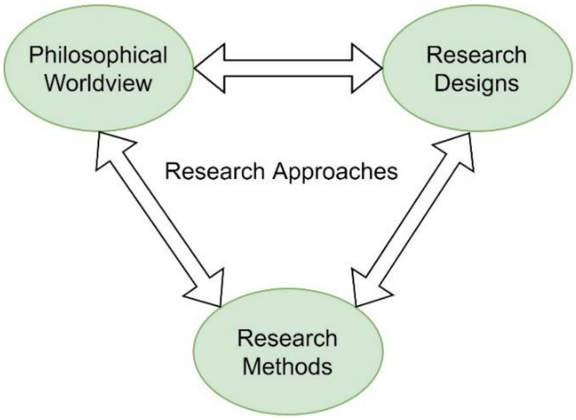


**Figure 4.2 Research framework (Adapted from Creswell, 2018)**

The researcher is not an interpretivist (or a constructivist). However, the researcher appreciates that a reasonable amount of qualitative data needs to be collected to guide her quantitative-based hypothetic-deductive reasoning leading to key research findings. Thus, the researcher selected the *pragmatic paradigm* which supports the researcher's positivistic/post positivistic orientation with the flexibility not to be overly locked in rigid ontologies and epistemologies. Within pragmatism, the researcher went on to adopt a mixed-methods research design (next section), wherein qualitative data informed the quantitative phase of the study aimed at hypothesis testing. Some scholars may view the researcher's worldview as postpositivist.

## 4.3 Research Design

Research design using mixed methods is influenced by a variety of factors that determine its configuration. The increasing recognition of the inherent complexity of real-world phenomena has prompted a surge in mixed-method research. Researchers seek to bridge the quantitative and qualitative gaps between quantitative and qualitative data by using mixed methods. There has been a growing demand for mixed-methods research designs, tailored to the specific research objectives and questions being addressed. As depicted in Figure 4.3 these designs are distinguished by sequential exploratory, sequential explanatory, and convergent designs, all with distinct characteristics (Creswell, 2018; Fetters et al., 2013).

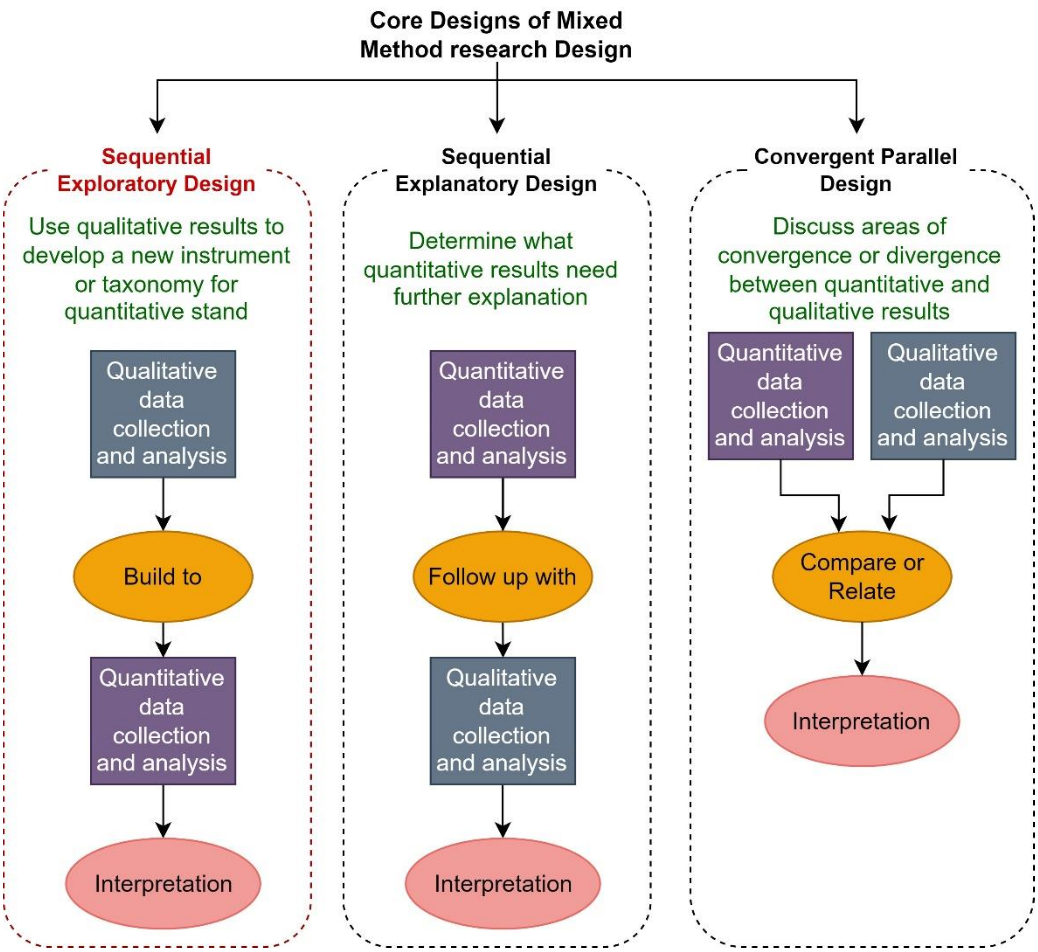


**Figure 4.3 Basic mix method designs (Adapted from Creswell, 2018)**

A sequential exploratory design begins with qualitative exploration before quantitative validation. This method is suited to situations in which findings on qualitative data need to enrich the research design with quantitative data (Lewis, 2015). A sequential explanatory design on the other hand uses quantitative analysis as a basis for qualitative exploration to guide empirical findings. Finally, a convergent parallel design facilitates concurrent integration of both methods of data collection and analyses simultaneously to gain rich transformative insights because discrepancies between qualitative data analysis findings and quantitative data analysis findings will be resolved through this type of a design. The three mixed method designs provide flexibility, allowing researchers to tailor their approach to the unique demands of their research inquiries.

The research adopts a mixed-methods approach, starting with a sequential exploratory design that emphasises qualitative exploration to define and scope constructs within the novel conceptual framework. This qualitative phase is crucial for in-depth industry engagement and understanding of LSS determinants, addressing the first research question (RQ1) about predicting and explaining quality performance through LSS implementation. The second research question (RQ2) investigates the role of uncontrollable project risks, necessitating further qualitative insights from industry practitioners. For the final question (RQ3), a more positivistic approach is used, focusing on examining the effect of the factor "Sector" on the goodness-of-fit of the researcher's model to quantitative data. This mixed-methods strategy ensures a comprehensive and adaptable approach to the research's unique demands.

### 4.3.1 Exploratory Sequential Design Chosen

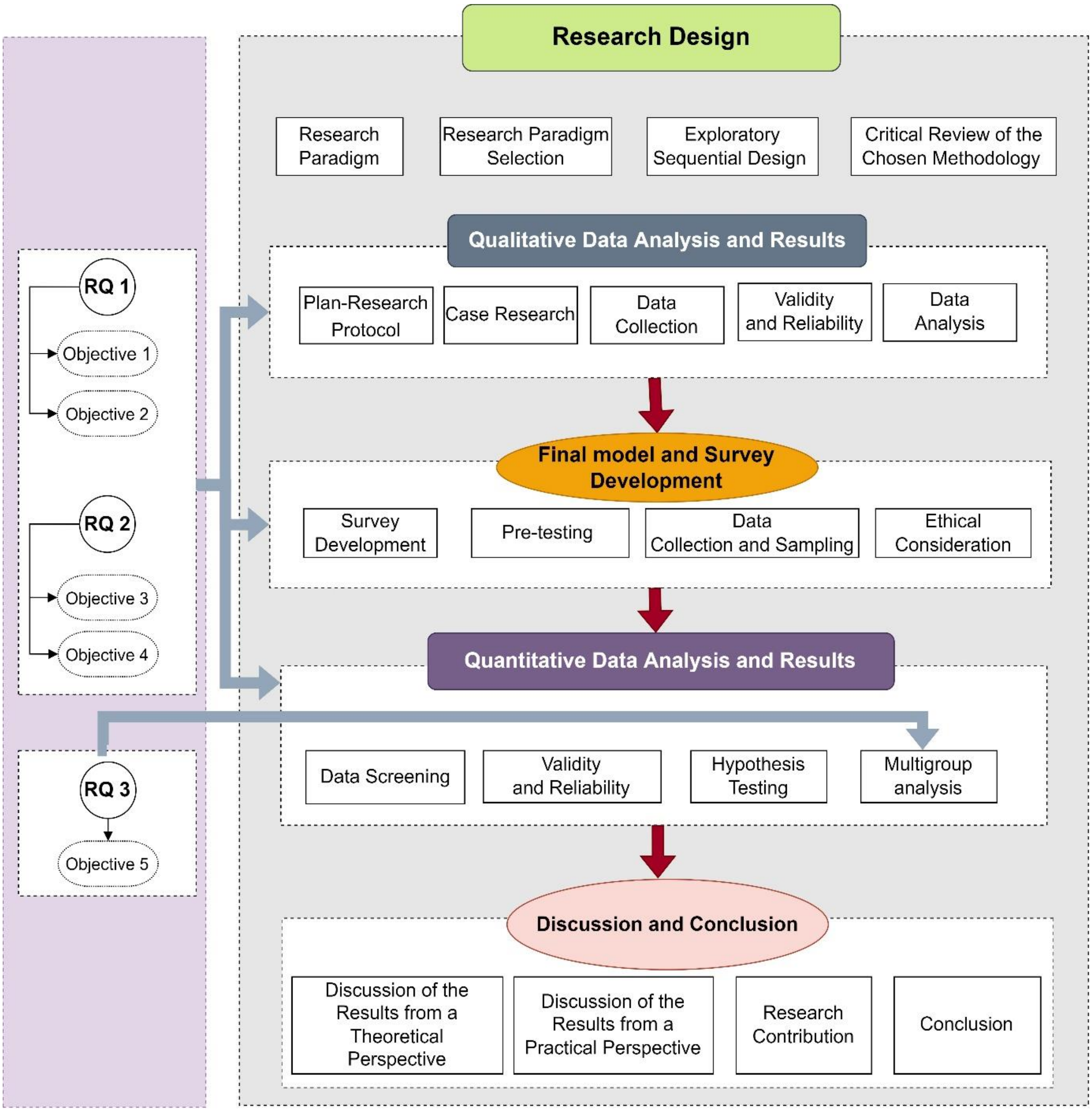


**Figure 4.4 Mixed Methods designs of the research.**

Of the three mixed methods research design platforms, the exploratory sequential design—the qualitative data collection and analysis informing the quantitative data collection and analysis—was found to be the one suitable for this research project. Figure 4.4 depicts different elements contained within each stage of the exploratory sequential design. In this study, qualitative exploration was initiated at the beginning of the investigation because testing the theoretical model for construct validity and statistical conclusion validity (hypothesis testing and implications) required the following: better understanding of the context of LSS as it is being practiced globally, scoping of the theoretical model with LSS practitioners globally, and a more complete understanding of the constructs, for the purpose of construct operationalisation for quantitative data collection. If the researcher was tightly locked into the quantitative paradigm (positivism), this would have compromised the research design due to doubtful construct operationalisation.

## 4.4 Qualitative Data Collection via Case Research

The research employed a case research methodology to address the research questions (Specifically RQ1), acknowledging its capacity for investigating phenomena within their natural context and gathering data from diverse sources, ultimately contributing to theory development (Benbasat et al., 1987; Voss et al., 2002; Yin, 2018). Even though case research has boundaries such as the limitations of the questionnaire and the generalisability of the findings, it can have high impact due to generation of rich context-bound information (Yin, 2018). As alluded to earlier, the case study method was used to collect and analyse data to understand LSS constructs under natural settings in order to generate rich information about the meaning of LSS constructs as well as how LSS is practiced today (Karlsson, 2009; Locharoenrat, 2018).

Qualitative data holds particular significance in addressing Research Question 1, which examines the constructs that determine LSS project performance as well as the relationships between the constructs (Perera et al., 2021a)[10]. It is important to note that the complexity of

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[10] RQ1 is concerned not just about the LSS determinants (constructs) but also about how these constructs predict and explain quality performance. Thus, RQ1 also prompts the researcher to determine the relationships between constructs (the test hypotheses that collectively constitute the theoretical model).

LSS projects extends far beyond quantifiable metrics and encompasses a variety of contextual factors influencing project outcomes. As a result of qualitative research (not to be confused with interpretivism or constructivism), information can be gathered and analysed to better understand LSS as a quality improvement approach in real-life settings. For example, project risk is a well-known concept, but this is the risk that would be considered before the fact (i.e., at the project planning stage). However, practitioners learn more about risk implications—more specifically, the uncontrollable risk—after project implementation. The nature of this unaccounted risk (residual risk) is not documented in the extant literature on LSS to be able to model unaccounted risk (residual risk) as a determinant on quality performance (project performance). This justifies the need to engage with LSS practitioners.

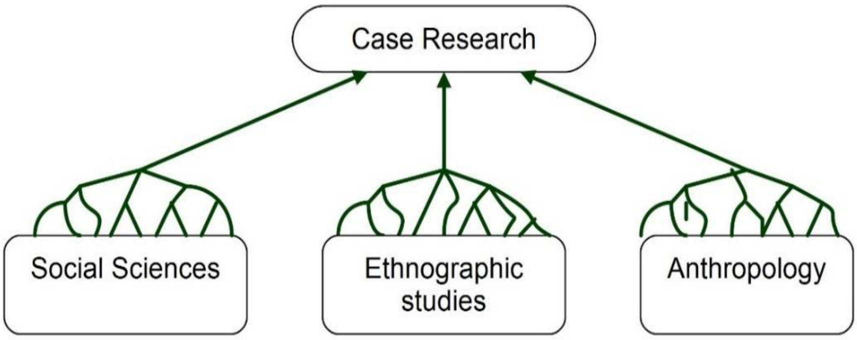



**Figure 4.5 The roots of case research.**

Case study research is a qualitative approach that focuses on understanding a phenomenon or case from multiple perspectives within a specific real-world context (Cope, 2015; Eisenhardt, 1989; Yin, 2018). A case study has its roots in a wide range of disciplines such as social science, ethnography, and anthropology. This makes the approach more naturalistic, holistic, and phenomenological, as shown in Figure 4.5. Several data collection methods, including interviews, observations, and document reviews, are utilised in this methodology to collect rich descriptive data (Chakraborty & Tan, 2012; Cope, 2015; Fakude, 2021). As it incorporates qualitative and quantitative evidence, case study research is especially useful for exploring complex phenomena and generating in-depth insights (Benbasat et al., 1987; Chakraborty & Tan, 2012; Yin, 2018). This said, the researcher used the case research approach advanced by Eisenhardt (1989) and Yin (2018) in the qualitative phase of the study. Some researchers (e.g. Beverland et al., 2010; Dubé & Paré, 2003) refer to the guidelines given by Eisenhardt (1989) and Yin (2018) as guidelines for positivist case study research. This is particularly important to be mentioned here because terms such as reliability and validity being used in relation to the researcher's case study mimics positivist thinking.

Figure 4.6 depicts, the steps involved in conducting rigorous research using the case research approach. The first step toward conducting a case study is to develop a conceptual model, formulate research questions, and to select a method (Lewis, 2015; Yin, 2018). As the second step of the case research process, the preparation of the data collection instruments, and the development of the research protocol are undertaken. Data collection involves interviews, observations, and document analysis (Cope, 2015). Analysing the collected data is the fourth step of the research process to identify patterns, themes, and relationships (Lewis, 2015). The fifth step in the research process involves the summarisation and interpretation of the results, which involves synthesising the findings and tying them together into meaningful conclusions.

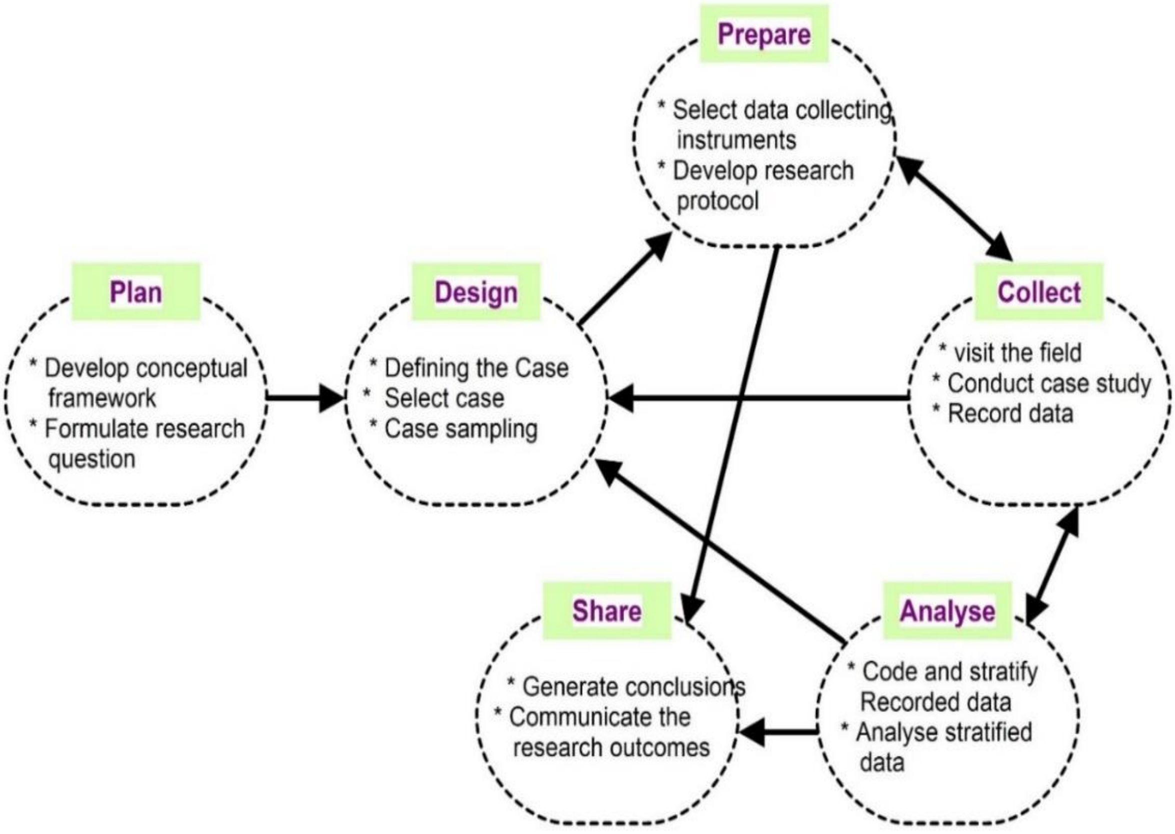



**Figure 4.6 Case research methodology (Adapted from: Voss et al., 2002 nd Yin, 2018)**

### 4.4.1 Planning and Designing the Case Research

A case search protocol or more specifically data collection protocol is a guideline that a case researcher creates to keep the case data collection and analysis uniform and consistent (Eisenhardt, 1989; Yin, 2018). Table 4.1 outlines the case research protocol of this study.

***Unit of Analysis***

In the design phase of case research, it is essential to carefully define the "case" (the unit of analysis) and its system boundary, as it is the "heart" of the case research (Miles & Huberman, 2014). Due to the integrated nature of LSS with organisational quality management systems, an " LSS project" was chosen as the unit of analysis (Scheller et al., 2018; Shah et al., 2008). Furthermore, studying single cases allows for in-depth exploration, but this approach raises concerns about generalisation, potential bias, and the risk of exaggerated conclusions (Miles & Huberman, 2014; Voss et al., 2002; Yin, 2018). To mitigate these issues, the researcher examined multiple cases across different regions, aiding in theory development and model assessment while reducing researcher bias.

Based on the interaction with participants in the case study, it has been concluded that treating the organisation as a unit of analysis could prove problematic when using quantitative methods—for example, because the execution can vary from one LSS project to another, providing responses keeping the average execution in mind could be subjected to significant systematic error (measurement bias). Similarly, many participants believed that quality performance and customer satisfaction from LSS implementation varied across projects, and the outcome should be evaluated in terms of Project Performance from specific LSS projects (Miles & Huberman, 2014; Yin, 2018). Thus, the study focused on the *last successfully completed project* as the unit of analysis. Focusing on a single project offers clear advantages in both qualitative and quantitative research phases (survey research), providing respondents with an anchor to respond to the questions. While using a single project as the unit of analysis could also introduce bias because respondents would potentially be influenced by their positive or negative experiences, this risk could be minimised in this study based on guidelines provided in the literature (e.g., Miles & Huberman, 2014; Voss et al., 2002; Yin, 2018). It is argued that comprehensive analyses of diverse, multi-regional, and multi-industry cases, coupled with a focus on the last successful project achieved, can effectively reduce potential biases.

### *Case Selection*

Having set boundaries prior to the interviews the researcher sought to combine similar results through literal replication (Yin, 2018). Literal replication, as opposed to theoretical replication seeks to select cases to predict similar results; theoretical replication on the other hand seeks to select cases to predict different results for theoretical reasons (Ridder, 2017; Yin, 2018). Since the study seeks to understand the drivers of successful LSS projects the researcher excluded organisations that lack maturity in LSS. Consequently, only managers who have successfully implemented LSS in their organisations for at least five consecutive years were considered. In addition, case sampling is closely related to boundary setting, as it clarifies the case setup, including details such as the time period, relevant social group, geographical area and type of evidence to be gathered (Benbasat et al., 1987).

During the course of a case research, it is common to evolve the sampling plan over time; however, it is best to test the sampling plan before executing it, taking into account the following factors (Miles & Huberman, 2014):

I. Does the sampling plan relate to the conceptual framework and research questions?
II. Is the sample representative of the phenomenon that is intended to be studied?
III. Does the sampling plan enhance the generalisability of the results?
IV. What is the feasibility of the sampling plan?
V. In addition to being ethical, does it provide any benefit to the informants?

The study determined the need for 16 cases based on information saturation, ceasing recruitment when no new insights emerged. Purposive sampling guided case selection (Patton, 2022; Woodside, 2010; Yin, 2014), aiming for a global representation of LSS organisations from New Zealand, Australia, the United States, Sri Lanka, and India to be used in case research. Thus, the cases were selected based on researcher’s judgement on the composition of organisations that met the researcher’s requirement. Most cases (six) were from New Zealand, the researcher’s country of residence favouring face-to-face interviews. Australia (2 cases) was chosen for the same reason (easy to travel), but due to the COVID-19 pandemic, the researcher could not travel to Australia unfortunately (upon completing the six New Zealand interviews face-to-face). The United States (US) was chosen because the origin of SS is the US, and it is easy to find world-class LSS organisations (4 cases were chosen) from that country. Further, two cases from India were chosen for its significant LSS presence. Two cases from Sri Lanka were chosen because it is always convenient conduct case studies in the face-to-face mode in the researcher’s native country due to language and cultural reasons. Table 4.1 lists the composition of the cases and the industries that they represent. An overview of each organisation involved in the case study is provided in Appendix C.

**Table 4.1 Case research protocol.**

| | | | |
|---|---|---|---|
| Unit of Analysis | Successful Project of LSS | | |
| | Boundary | Involvement: | At least one LSS black belt |
| | | Saving (USD): | >$15,000.00 |
| | | Important Improvement: | Projects consisting of an SS element aimed at reducing variation are considered as Advanced Improvements, and projects aimed at eliminating wastes through Lean element are identified as Quick wins. Projects can also use both components of LSS and their tools in tandem. |
| | | Project Duration: | <6 months |
| Case Selection | Multiple Cases | To obtain external validity as well as to overcome researcher bias, multiple cases will be conducted will be conducted. A pilot run will set to test the interview questions. | |
| | | Boundary | Individual: Involve LSS Black Belt<br>Industry: Manufacturing and Nonmanufacturing |
| | Longitudinal | Investigate through current data | |
| Data Sources | Sampling | A "literal replication" is expected from the study to predict similar results | |
| | Interview data | The interview will be guided by a semi-structured questionnaire, keeping in mind the purpose of the interview (Yin, 2018). The Interviewee's consent will be sought to record the interview. The interview data would be the main source of data during the case study phase. | |
| | Secondary Data | Appropriate secondary sources will be solicited from the interviewee, if necessary, based on what transpires through the conversation (e.g., Lean application such as visual records, value stream maps used for LSS projects | |
| Data Entering | Voice to text automation (AI) | Voice recognition software (voice to text) such as Dragon/Otter will be trialled after calibration (training) to check whether manual transcribing can be avoided | |
| | Manual | To confirm the results of the speech to text conversion a review will be performed manually | |
| Data Analysis | Researcher | Data will be coded manually since the interview responses are expected to converge | |
| | Second Coder | A second coder will review the coded data to avoid researcher bias | |
| Thematic Development | Manual | Thematic analysis will be performed and identify emerging themes. Next build discussions and conclusions related to themes reflecting the natural existence of LSS phenomenon. Then a comparison will be conducted to identify the uniqueness of successful implementation of LSS in Australasian region. | |

**Table 4.2 Profiles of interview respondents**

| Case Org. | Organisation type | LSS Maturity | Designation of the Participant | Respondent's LSS Experience | LSS Credentials | Country |
|---|---|---|---|---|---|---|
| MO-1 | Manufacturing | 15 | General Manager of Business Excellence | 18 | LSSBB | NZ |
| NMO-2 | Healthcare | 5 | Improvement Advisor (Consultant) | 8 | LSSMBB | NZ |
| NMO-3 | Service | 13 | Senior External Consultant. | 8 | LSSBB | NZ |
| MO -4 | Manufacturing | 16 | Senior Manager | 12 | LSSMBB | NZ |
| NMO-5 | Consultancy | 29 | Senior Consultant | 14 | LSSMBB | NZ |
| MO -6 | Manufacturing | 15 | Process Reliability and Improvement Engineer | 7 | LSSBB | NZ |
| MO -7 | Manufacturing | 14 | National Continuous Improvement Manage | 11 | LSSMBB | AU |
| NMO-8 | Service/Telecommunication | 6 | Process Transformation Manager | 7 | LSSMBB | AU |
| MO -9 | Manufacturing | 20 | Corporate Reliability Lead. | 22 | LSSBB | US |
| NMO-10 | Service | 19 | Lean Expert | 21 | LSSMBB | US |
| MO -11 | Manufacturing | 31 | Senior Manager in Systems Engineering (in R&D). | 30 | LSSMBB | US |
| NMO-12 | Service/ Agriculture | 17 | Service Manager | 16 | LSSMBB | US |
| MO -13 | Manufacturing | 13 | Director Continuous Improvement | 10 | LSSMBB | SL |
| NMO-14 | Service/Telecommunication | 16 | Quality Assurance Lead | 14 | LSSBB | SL |
| MO -15 | Manufacturing | 16 | Senior Manager | 18 | LSSBB | IN |
| NMO-16 | Healthcare | 6 | Continuous Improvement Lead | 11 | LSSMBB | IN |

Notes:

1. *LSSBB/LSSMBB means* LSS Black Belt or LSS Master Black Belt.

2. Country Interview Sequence is New Zealand (NZ) → Australia (AU) → United States (US) → Sri Lanka (SL) → India (IN)

3. MO means a manufacturing organisation; NMO means a nonmanufacturing organisation.

### 4.4.2 Case Research Preparation

A crucial element of case research remains the selection of the appropriate data collection method. Case research instruments refer to tools and techniques employed to collect data in case research. The most common instruments include interviews, observation, document analysis, physical artefacts as shown in Figure 4.7. Consequently, case research utilises multiple data collection methods to obtain data to capture the complexity of real-world situations (Crowther & Lancaster, 2008). However, Voss et al. (2002) assert that structured/unstructured interviews, coupled with interactions with participants, constitute the primary data sources for many case research studies. Research instruments vary according to the nature of the research and the specific case being studied (Stalp, 2008). Thus, the researcher carefully analysed and designed instruments (interviews, archival records) that align with research objectives to enhance the validity and reliability of the results.

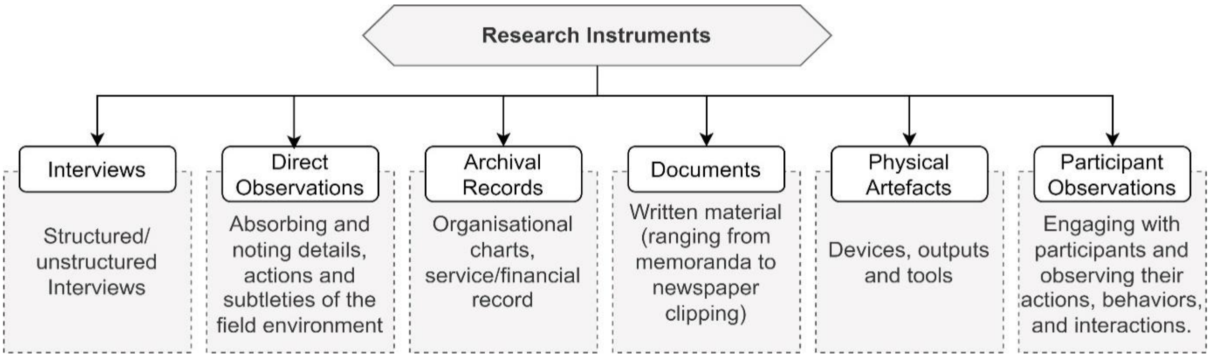



**Figure 4.7 Six sources of evidence in case research**

### 4.4.3 Data Collection via the Sixteen Case Study Participants

Generally, qualitative data collection procedures can be classified into two categories: retrospective data collection and longitudinal data collection (Lewis, 2015; Miles & Huberman, 2014). A retrospective approach involves the collection of data at one point in time, while a longitudinal approach involves the collection of data over an extended period. Due to time and resources constraints, the retrospective approach was selected. Semi-structured questions (See Appendix B) were administered upon the case study participants in the form of a separate interview for each participant. The semi-structured interviews served as the primary source of data collection. Where possible information on the LSS project charter and evidence of structured problem-solving examples was collected from the participants. Some participants (e.g., the participant representing a leading aircraft manufacturer in the US) declined to provide project records due to confidentiality reasons. When possible, the said secondary information were used as corroboration evidence of verbal responses to semi-structured interviews. To avoid researcher bias, the interviews were recorded using a miniature digital voice recorder, while preserving data transparency (online interviews were recorded in Zoom as well). Figure 4.8 summarises the choices graphically.

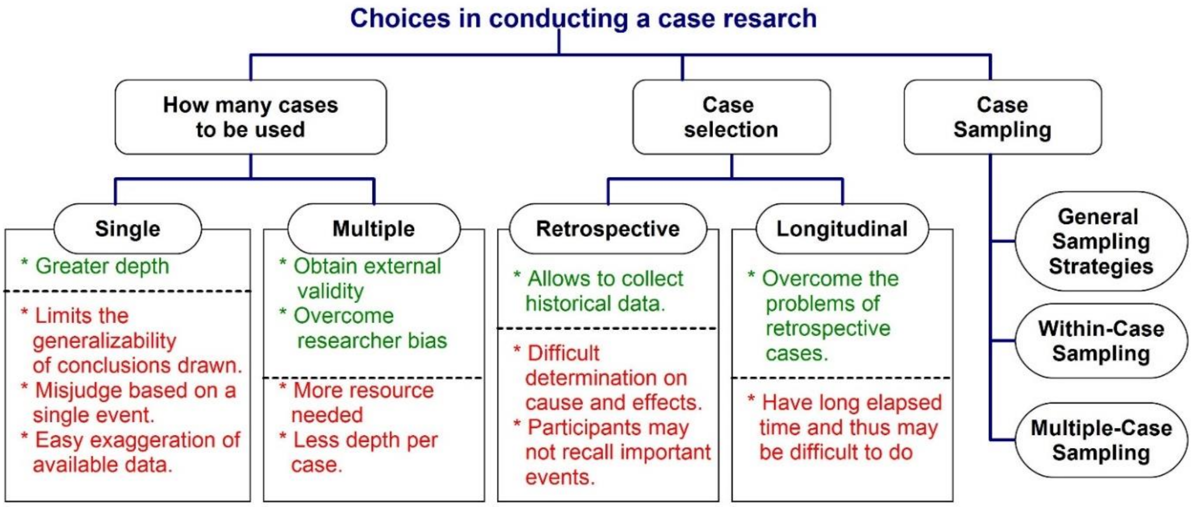



**Figure 4.8 Developing case research protocol**

By utilising existing literature on the conceptual model as the starting point, the case study (semi-structured interviews) focused on better describing the determinants of LSS project success. In semi-structured interviews, participants shared their experiences and insights on LSS while being guided by the researcher, keeping the conceptual model as the guiding framework.

The case study required a significant shift in methodology due to the outbreak of the COVID-19 pandemic. The initial four cases in New Zealand were conducted using traditional face-to-face interviews, but due to adverse effects associated with the pandemic, the remaining interviews were conducted using virtual platforms including Zoom and Teams meetings. Online interviews posed several challenges, including difficulties in securing secondary data, which is an important aspect in the triangulation in a qualitative data collection phase. Connectivity and audio quality issues, in addition to technological glitches occurred occasionally (e.g., on one occasion the Zoom cloud recording was not received when the Zoom connection was disrupted), but the researcher made every effort to maintain the interview flow and depth of questioning. Considering the circumstances mentioned above, online interviews proved to be quite adequate in collecting the requisite data.

### 4.4.4 Construct Validity and Reliability as Applied in Case Research

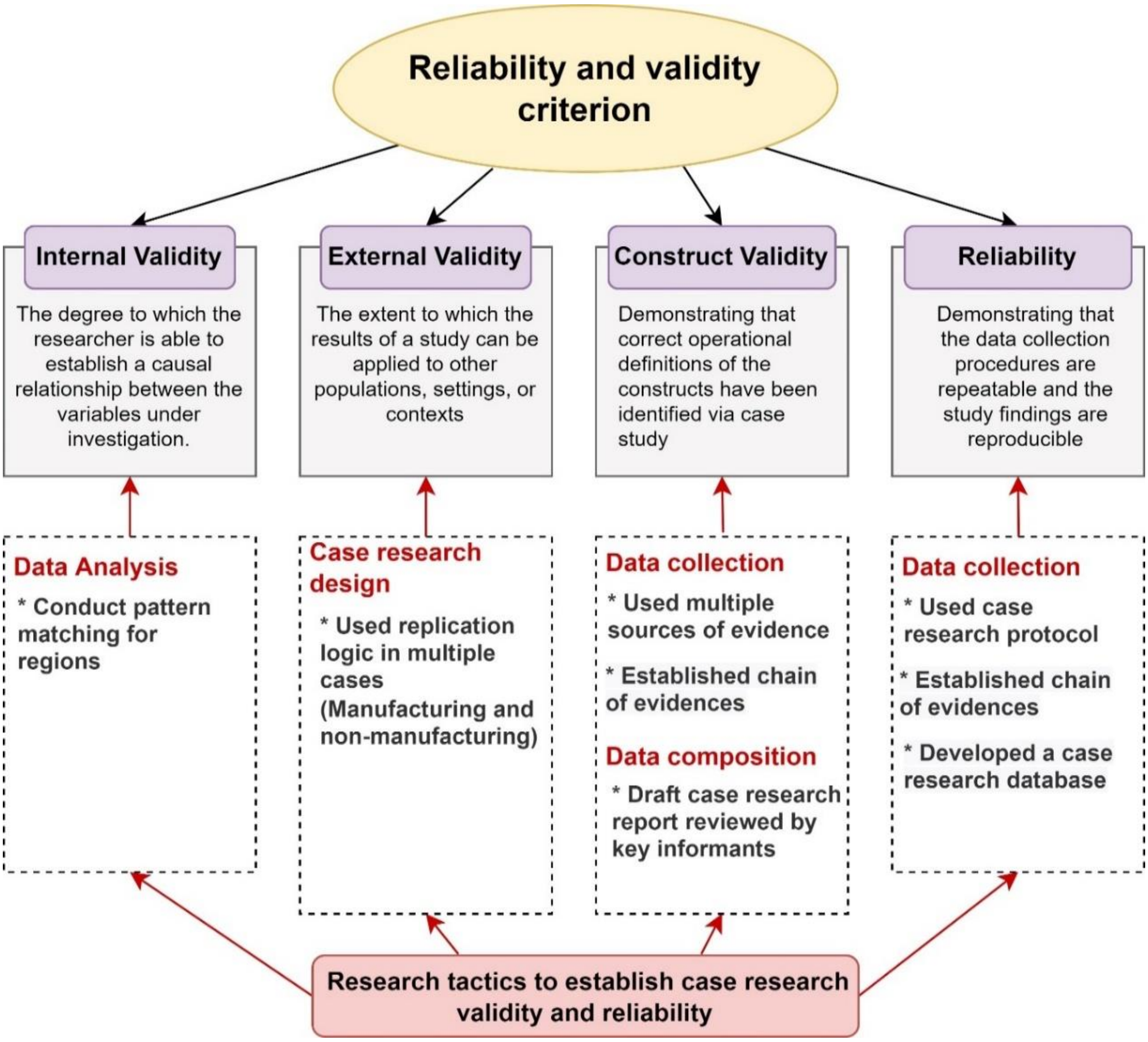



**Figure 4.9 Criteria for establishing validity and reliability in case research (Source: Yin, 2018)**

Although internal validity, external validity, construct validity, and reliability are commonly associated with positivist (quantitative) methodologies, Yin (2018) and Eisenhardt (1989) describe these concepts as being used in postpositivist case research. To be relevant to an operations management context, Yin and Eisenhart's research has been repackaged by Voss et al. (2002)[11]. The researcher uses hypothetical-deductive reasoning during the quantitative

[11] Their updated version in 2015 provides even a more positivistic friendly description. See Voss, C., Johnson, M., & Godsell, J. (2015, 2015-06-28 – 2015-07-01). Revisiting case research in operations management. 22nd International Annual EurOMA Conference, Neuchâtel, Switzerland.

phase as a complement to his or her later use of validity concerns and reliability. Construct validity in case studies involves ensuring accurate operational definitions, while reliability focuses on consistent data collection and reproducible findings (Yin, 2018). Unlike positivistic case studies, interpretivist case studies emphasise the trustworthiness and credibility of findings (Guba, 1981; McGloin, 2008). Quality evaluation in qualitative research lacks rigid criteria (Dubé & Paré, 2003; Eisenhardt, 1989; Stalp, 2008; Yin, 2018), but Yin (2018)'s four criteria provide a structured framework for assessing case research validity and reliability. Figure 4.9 details these criteria and associated research tactics.

There are various strategies that researchers employ to establish validity and reliability in case research (Creswell, 2018; Morse, 2016). This research employs pattern matching, a key strategy for internal validity recommended by authorities such as Eisenhardt (1989) and Yin (2018), as detailed in section 4.4.5. For external validity, diverse sampling and replication logic was employed. The study selected participants from various industries covering both manufacturing and nonmanufacturing organisations. Literal replication and semi-structured interviews ensured comparable results (Yin, 2018). To enhance the construct validity of the case research, the researcher used multiple sources of evidence, pretesting data collection instruments, and a peer review process in which participants reviewed the information and interpretation provided by the researcher. To enhance reliability, the researcher established a systematic and well-documented data collection, analysis, and interpretation process. Standard data collection protocols, inter-coder reliability checks, and systematic coding procedures were implemented to ensure consistency. In Perera et al. (2021a), the researcher outlined a detailed protocol for the case study and clearly documented methodological decisions to allow other researchers to replicate the study.

### 4.4.5 Case Study Data Analysis

A comprehensive textual record was created as a first step in qualitative data analysis. Considering that this research questions practitioners regarding concepts and topics pertinent to LSS project initiation and implementation, a qualitative approach was necessary rather than traditional coding, which is typically used in content analysis (Braun & Clarke, 2020; Hsieh & Shannon, 2005; Yin, 2018). Data analysis was therefore conducted using qualitative content analysis. This method allows textual elements to be divided into a limited number of categories

(Woodside, 2010; Yin, 2018). Accordingly, researchers can assign codes (categories) to text segments of varying lengths as long as they represent a single theme or issue related to the research questions.

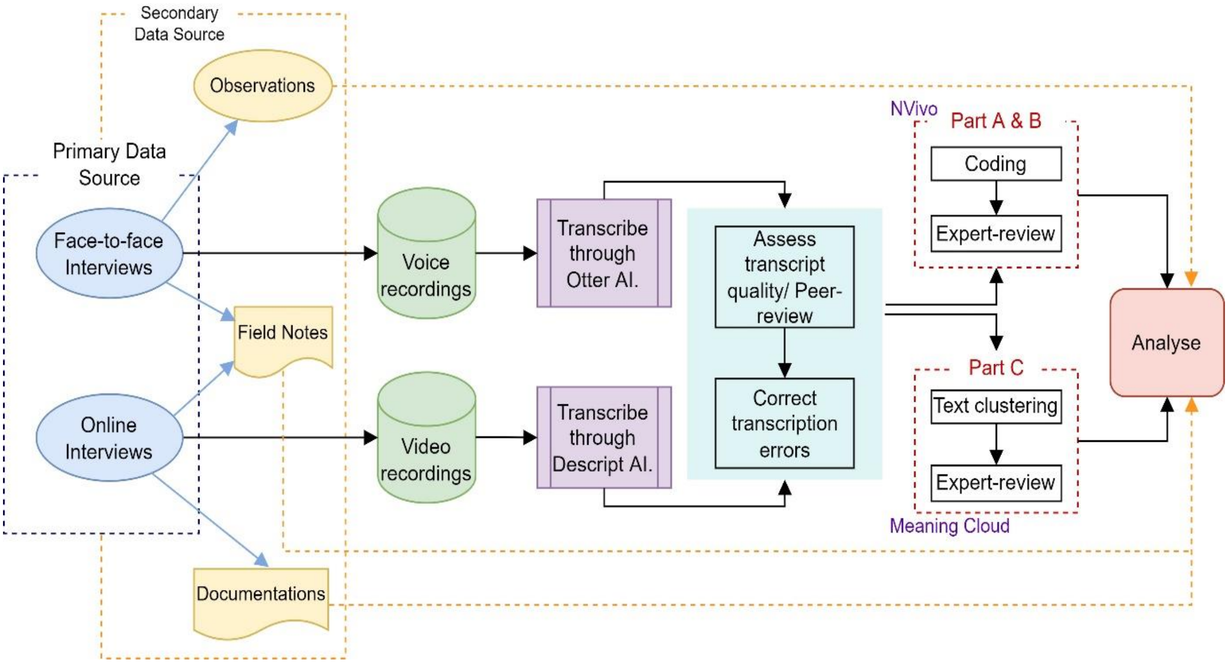



**Figure 4.10 Case research pre-analysis process**

Figure 4.10 outlines the pre-analysis stage of case study data, involving transcribing, peer-reviewing, coding, and expert review for coding quality. The collected data encompassed voice recordings, field notes, and LSS project documents from face-to-face interviews, and video recordings for other cases. Advanced 21st-century technologies, particularly AI, were utilised for efficient transcription. The use of AI has become increasingly popular in both research and practical applications (Dwivedi et al., 2022). Semi-automated transcription and scoring procedures, are tailored to research needs to improve efficiency and advanced analysis. There are many speech-to-text AI tools available on the Internet, including Google Cloud's speech-to-text service (Northcutt et al., 2023; Scharenborg et al., 2020) and Otter-AI. The accuracy of these services is calculated using algorithms based on word error rates (Dwivedi et al., 2022; Northcutt et al., 2023). For this research, a free version of Otter-AI was used to transcribe the audio transcriptions of face-to-face interviews[12] and Descript.AI for video transcription. With

[12] The free version comes with a limitation on the number of words per file, but this was not a limitation in this research.

these AI tools, which were chosen for their ability to recognise languages and accents, a cost-effective and accurate alternative to transcription was offered. Post-transcription, manual evaluations, error checks, and peer reviews ensured data accuracy, leveraging AI's efficiency while maintaining traditional quality checks.

Part B of the semi-structured interview questionnaire (Appendix B) was designed to gather detailed descriptions of LSS project planning and implementation. Respondents' open-ended answers were subject to thematic analysis, a common method in qualitative research for identifying recurring themes within complex textual data. This analysis involved coding responses and categorising them into themes. NVivo software, a tool frequently used in qualitative research for managing and analysing data, was employed for this purpose. An illustration of this thematic analysis process, particularly for understanding an LSS project as per Part B- question 1, is shown in Figure 4.11.

Part C of the interview questionnaire aimed to operationalise concepts/constructs for developing a survey instrument to collect quantitative data and test the theory. Respondents' answers were clustered using Meaning Cloud, a Microsoft Excel add-in, for designing survey instruments. This tool grouped various indicators for each construct based on respondents' perceptions, aiding in the development of a measurement scale. Meaning Cloud's use of text analytics and natural language processing techniques facilitated the grouping of similar measurement items, saving time and ensuring more accurate construct manifestations. The results from Part C are detailed in Chapter 6.

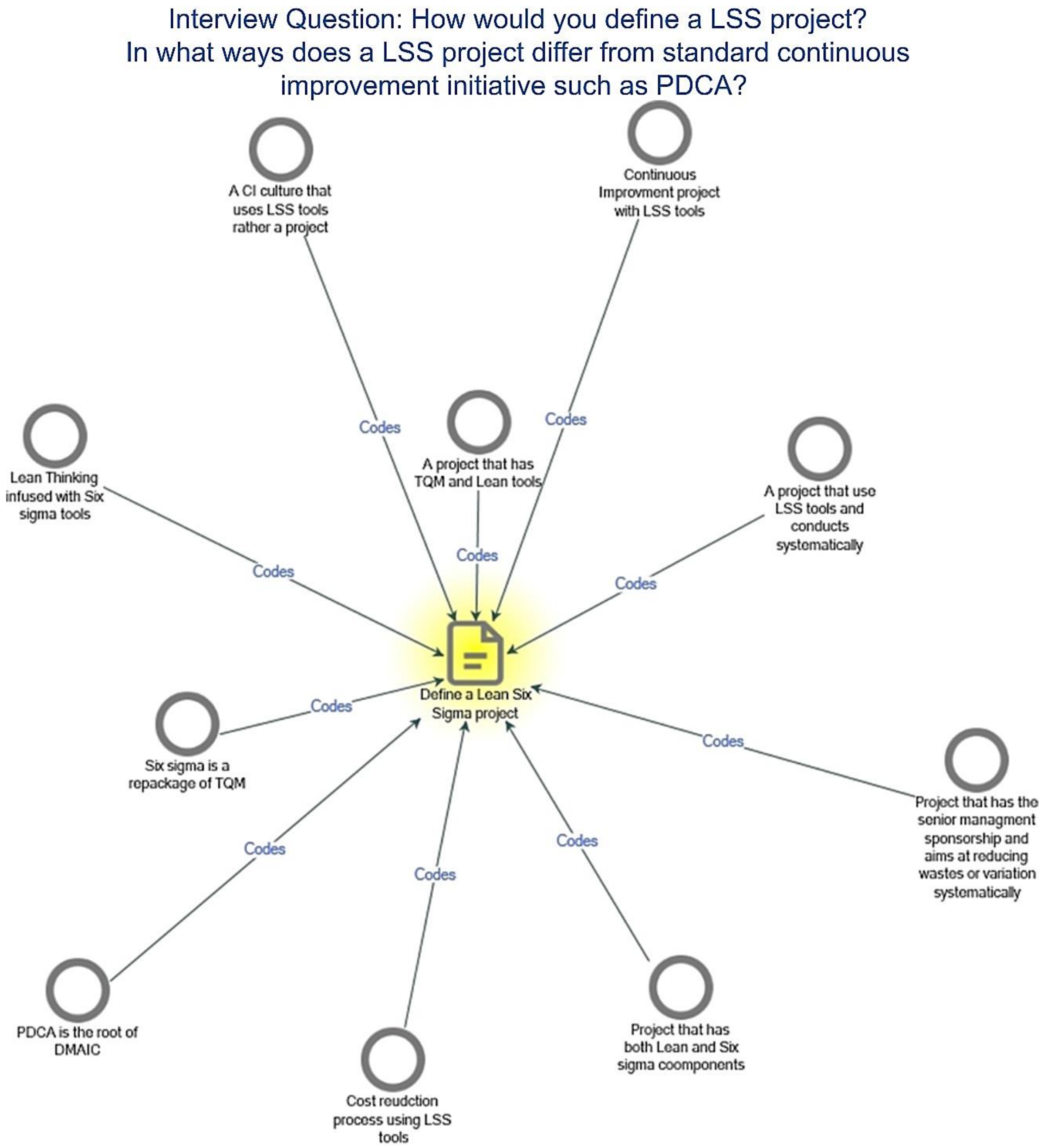



**Figure 4.11 Example of thematic analysis performed on understanding an LSS project**

Qualitative content analysis can be classified into three main approaches: conventional, directed, and summative approaches (Hsieh & Shannon, 2005). In the conventional approach, categories are coded directly from textual data; in the directional approach, the coding is guided by the theoretical framework or findings leading to theory development; in the summative approach, the coding is guided by counting and comparing content. In this research, directed qualitative content analysis was employed, aligning with the deductive nature of the study aimed at refining the conceptual framework for LSS project success. The process involved a thorough review of interview transcripts to highlight segments relevant to LSS implementation. These segments were then coded according to predetermined conceptual categories (Figure 4.12).

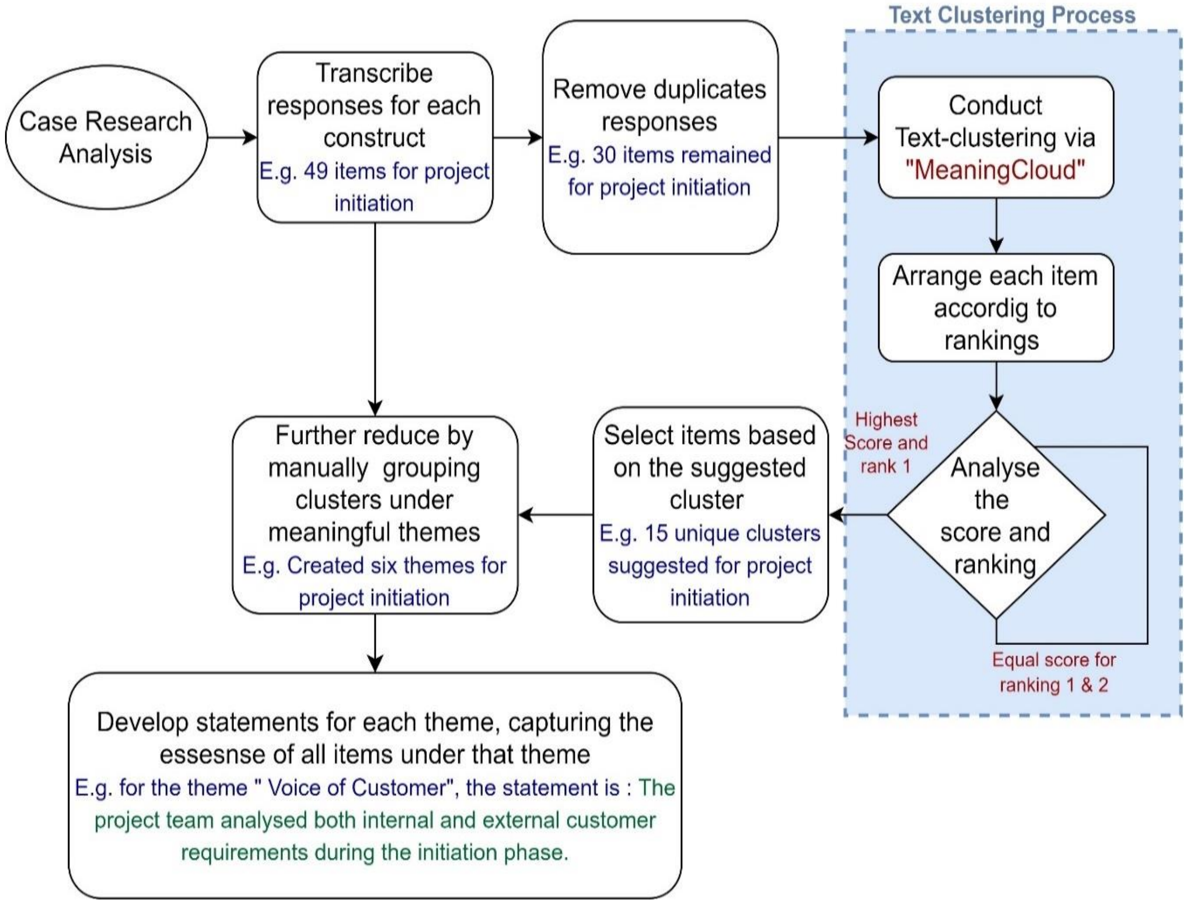



**Figure 4.12 Case research analysis process directed to project initiation**

The entire interview transcript was reviewed before directing content analysis. The researcher then identified and highlighted segments that initially highlighted certain aspects of LSS implementation. In the next step, these identified segments were coded according to predetermined conceptual categories. The primary data, collected via semi-structured interviews, were categorised into constructs like Leadership Engagement, LSS Project Initiation, and others, as per the conceptual model. This involved identifying patterns using a text clustering process for an in-depth understanding (Yu et al., 2014). Figure 4.12 illustrates the deduction process for the "LSS project initiation" construct. This approach was pivotal in analysing both the positive outcomes and negative impacts associated with LSS projects, enhancing the overall research conclusions.

## 4.5 Survey Design to Collect Quantitative Data for Hypothesis Testing

The refinement of the model through case research and the operationalisation of constructs played a vital role in the design of the survey. Several critical steps were involved in ensuring that the survey instrument was theoretically sound, and the survey administration was methodologically sound. These steps are as follows:

1. *Deriving the Final Model and the Hypotheses:* Developing an effective survey begins by refining the research model based on insights gained from case studies. It is important that the refined model encompasses the key relationships, variables, and factors that emerged from the literature as well as the findings of the qualitative analysis. This refined model forms the basis for hypothesis formulation, setting clear expectations regarding the relationships to be tested in the subsequent quantitative phase.

2. *Operationalisation of the Constructs*: Operationalising constructs bridges the gap between theory and practice through qualitative insights. In essence, it refers to the process of translating abstract concepts derived from literature and reflected in qualitative data into concrete, measurable indicators. Extant literature was used to operationalise well-established constructs such as Leadership Engagement and CI Culture. However, operationalisation of emerging constructs (e.g., Project Residual Risks) as well as constructs that have not been operationalised before in SS or LSS contexts (e.g., LSS Project Initiation, and LSS Project Execution) required insights from the qualitative study (the case research).

3. *Expert Review of the Operationalised Constructs for Content Validity*: The operationalised constructs were subjected to expert review to ensure content validity. The operationalisation of well-established constructs such as Leadership Engagement and CI culture required minimal effort during an expert review. However, emerging constructs as well as constructs that have not been operationalised before required more involvement of the experts to establish content validity/face validity. The content validation team ($n$ = 4) included subject matter specialists and methodologists, who were asked to evaluate the clarity, relevance, and appropriateness of the items designed to capture each construct. A consensus was reacted among experts on the contents

(measures of the constructs, as they are expressed in the survey instrument) after a three-round iterative process, which was moderated by the researcher.

4. *Logical Flow of Contents*: A refined model, operationalised constructs, and expert-reviewed measurement instruments provide the foundation for survey design. Therefore, the researcher designed the survey instrument (also sometimes referred to as the survey questionnaire), including the arrangements of items, response scales, and any additional questions necessary to obtain data. A clear and logical flow of the survey instrument was maintained to minimise respondent burden and to ensure the quality of the data collected.

### 4.5.1 Survey Instrument Development

In addition to facilitating the collection of structured data, a survey instrument (questionnaire) serves as a conduit through which researchers can gain insights and answers to their research questions in situations where in-depth information on the context or the concepts are not needed (Brace, 2018; Saris & Gallhofer, 2014). In hypothetic-deductive approaches, accuracy and reliability of the measurement scales is needed, and as mentioned earlier, a well-deigned survey instrument administered to the right participants achieves these requirements very efficiently. The questionnaire contained two parts. The first part contained general questions aimed at obtaining demographic/secondary information and contextual information of the participants and/or their firms. The second part, the main part contained several statements related to each construct for which the agreement was sought on a seven-point Likert scale (1: Strongly disagree and 7: Strongly agree) from each participant (see section 4.6.2 for more explanation). construct shows how many questionnaire statements represent each construct. Each statement acts as an indicator variable (this can also be called an indicator, a measure, or an item) of its construct in the statistical modelling. For example, the measurement scale of the Leadership Engagement contains four measures (items) and the correlations between these four items (inter-item correlations) show how internally consistent (reliable) the underlying measurement scale is.

**Table 4.3 The Number of statements in the questionnaire that represent each construct**

| Construct | Number of Statements |
|---|---|
| Leadership Engagement (LE) | 4 |
| CI Culture (CICUL) | 14 |
| LSS Project Initiation (PRIN) | 6 |
| LSS Project Execution (PREX) | 8 |
| LSS Performance (LSSPER) | 8 |
| Project Residual Risks (PRRISK) | 5 |
| Total | 45 |

### 4.5.2 Survey Administration

Each potential participant of the survey was invited to participate in the study with a very brief introduction to the study. As soon as participants accepted the invitation, the researcher communicated with them providing more details about the research and expressed appreciation for accepting the invitation. As the last step, the researcher provided a short covering letter formally introducing the study and the online questionnaire and provided each potential participant a link to respond to the survey. The survey was administered to participants using the Qualtrics electronic survey administration platform. Figure 4.13 illustrates the process flow associated with the administration of the survey.

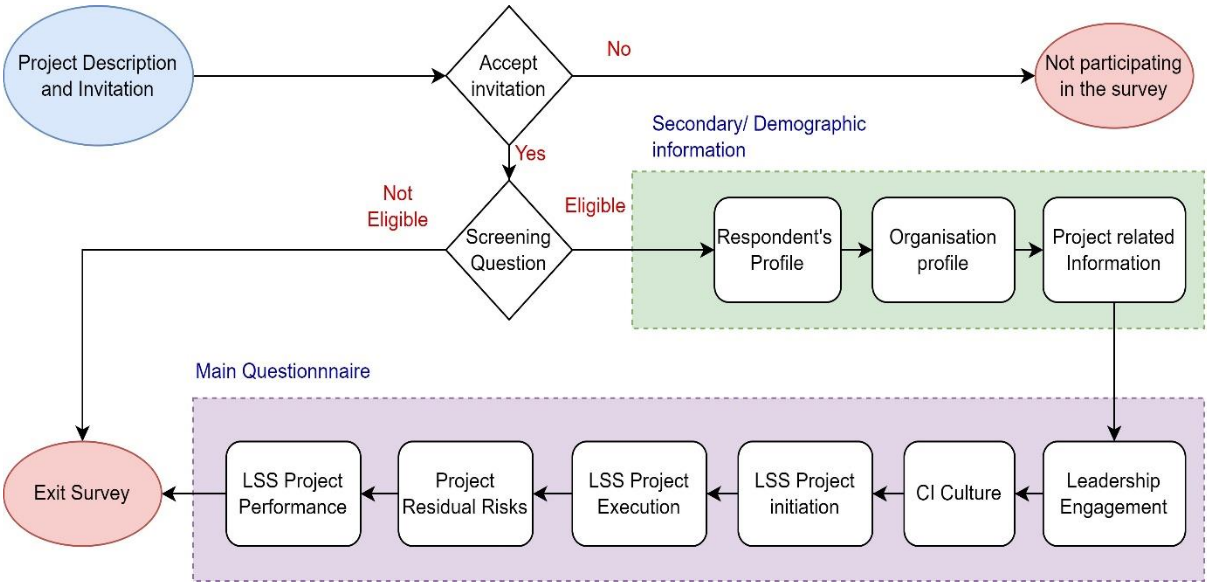



**Figure 4.13 Research questionnaire flow**

### 4.5.3 Initial Testing of the Survey Instrument: Pretesting and Pilot Testing

Before administering a survey instrument on a full scale, preliminary testing, including pretesting and pilot testing, is crucial to minimise risks and ensure construct validity (Ruel et al., 2016). Pretesting, conducted with a small group of experts, aims to evaluate the instrument's clarity, appropriateness of responses, and potential for survey fatigue (Bowden et al., 2002; Carter et al., 2020; Ruel et al., 2016). Academics are well suited for this. In this study, a pre-test of the questionnaire was accomplished by using (interviewing) three experts with extensive academic backgrounds (all three had PhDs) in industrial engineering and operations management. This process led to the rewording of some questionnaire statements. In contrast, pilot testing—the survey's "dress rehearsal"—involves a larger group (30-100 participants) to identify methodological weaknesses, such as sample selection and response bias (Bowden et al., 2002; Ruel et al., 2016). Since pilot tests involve no close contact with participants, and full-blown survey conditions must be replicated, respondents were invited to participate in the survey online (Ruel et al., 2016).

A pilot test was conducted by the researcher between 3 May 2022, and 17 May 2022. 108 individuals were invited, but only 36 responded, giving an acceptable response rate of 33.3%. Despite the possibility of repeating the pilot test multiple times, based on the feedback received, it was deemed unnecessary. Participants were asked to rate the survey design based on three markers: well-designed, average, and needs improvement. The survey was rated well-designed by 26 respondents (72.22%), average by eight respondents, and needing improvement by two respondents (0.06%). The researcher, however, did not receive written feedback on the survey's clarity, questions, or critical improvement suggestions even from the two respondents who said the survey needed improvement. Thus, the two respondents were labelled as pessimists. To determine whether the response pattern of the two pessimist respondents differed from the response pattern of the remaining 34 respondents (line graphs were used), the researcher mapped the data collected from the two pessimist respondents against those collected from the remaining 34 respondents. No discrepancy was detected. Thus, the pilot data suggested that scale reliability and discriminant validity of the constructs will likely to be satisfactory once tested on a large sample.

## 4.6 Quantitative Data Analytic Considerations

### 4.6.1 Types of Quantitative Research Designs

Quantitative research is a systematic empirical investigation that seeks to numerically quantify and analyse causal predictive phenomena via structured data using statistical analysis analysis (Clark & Ivankova, 2016; Creswell, 1994). Among the characteristics of this research approach are its focus on measurable variables, large sample sizes, and rigorous methodologies for establishing or confirming relationships, or/and patterns to provide generalisable conclusions. There are four types of quantitative research designs: descriptive, correlational, quasi-experimental, and experimental designs (Bloomfield & Fisher, 2019; Bryman & Cramer, 2003; Winston & Blais, 1996).

A *descriptive design* is suitable when the goal of data collection is to describe individuals, groups, and organisations, as opposed to finding associations or causal links between variables. A *correlational design*—a term used interchangeably with the term survey research design—is suitable when the goal is to examine the strength and direction of the relationships between independent and dependant variables, without having to determine causality (i.e., which variable(s) caused which (Bloomfield & Fisher, 2019; Bryman & Cramer, 2003). An *experimental design* on the other hand involves manipulating variables (potential causal variables) and to examine the effects of these variables on the outcome variable (effect variable) in order to assign causality (Bloomfield & Fisher, 2019; Levy & Ellis, 2011). A *quasi-experimental design* attempts to achieve the goal of an experimental design without fully controlling the background variables (due to practical reasons) that can affect the cause-effect relationship(s) (Bloomfield & Fisher, 2019; Bryman, 2012; Winston & Blais, 1996).

The researcher adopted a correlational research (survey research) design to collect data to examine the association between independent variables (X variables) and dependant variables (Y variables), using correct statistical methods (details in section 7.7). A correlation between X and Y variables is one of the necessary requirements for demonstrating causality (X variables causing the Y variable/s). The other two necessary requirements for demonstrating causality are *temporal precedence* and absence of spurious effects (Duncan, 1966; Sechrest, 2005). Temporal precedence means, the cause variable/s (e.g., Leadership Engagement) acting before the effect variable/s (e.g., CI Culture acting before LSS Project Initiation). In the researcher's case, the temporal precedence comes from the researcher's theory/model specification, which was done carefully in Chapter 3. The absence of spurious effects (the third variable effect colloquially speaking), which is a more challenging proposition to demonstrate, again came from the researcher's argument that the theoretical model has been correctly specified (Chapter 3), in the sense there are no unaccounted causal variables that cause the co-variation between independent and dependant variables. Having specified the model carefully in Chapter 3, the researcher argues that the correlational research technique(s) used by her (based on data collected via survey research) enables her to confirm or refute her causal predictive hypotheses.

There are two types of survey research designs: cross-sectional and longitudinal. A Cross-sectional design is meant to collect data on variables from participants at one point in time. A longitudinal design on the other hand collects data on variables from the same participants multiple times over a specified period. The researcher used cross sectional data as opposed to longitudinal data not just because she had a limited time window to collect data, but also because her unit of analysis is an LSS project completed by the company (one time event). Longitudinal data would have been useful to determine whether firms have been able sustain quality improvement, but that is not an objective of the study, although this aspect was covered in the *case research* (see interview question #10 in Appendix B) as a part of scoping the conceptual/theoretical model in the industry.

### 4.6.2 Addressing Bias and Systematic Error

Unlike random error associated with measurements, there are no known ways of isolating systematic error in statistical modelling, unless systematic error is due to a known amount of measurement bias rather than due to the (wrong) way the research design has been conducted (Nunnally & Bernstein, 1994). Systematic error can manifest in both these forms, that is, measurement bias and research design discrepancies.

Although survey research designs are used extensively to collect quantitative data on research across diverse subject areas and they are extremely efficient (Creswell, 2018; Ilieva et al., 2002; Jakobsen & Jensen, 2014), with this advantage comes the disadvantage of inviting bias in the form of *non-response bias*, and CMB in the data, which can affect the results due to systematic error (Jakobsen & Jensen, 2014; MacKenzie & Podsakoff, 2012; Podsakoff et al., 2012).

Among the methods used to mitigate non-response bias, researchers use multimode collection strategies (web-based, email, and social media), and use reminders soliciting participants to participate in the study if they have not done so (Jakobsen & Jensen, 2014). As a strategy to mitigate CMB—this form of bias results in variability of data owing to the way in which the survey is conducted rather than due to constructs—suitable and willing participants were invited to participate in the study (MacKenzie & Podsakoff, 2012; Podsakoff et al., 2003).

There is a significant concern regarding CMB in survey research. CMB is a systematic error that occurs when respondents' responses are affected by the method of data collection rather than due to constructs that are being tested. As a result of this bias, relationships between variables can be inflated and research findings can be inaccurate, which may compromise study validity (Jakobsen & Jensen, 2014; Podsakoff et al., 2003). The results of a survey can be distorted in several ways due to CMB. For example, respondents may feel compelled to provide politically correct answers constantly, which may lead to artificially strong associations between variables (Baumgartner & Weijters, 2021; Podsakoff et al., 2012). It is also possible that phrasing or ordering of the questions could inadvertently suggest a desired response, resulting in biased results. CMB can also originate if the same data collection method (e.g., self-report surveys) is used to collect data on both independent variables and dependent variables or some method-specific factors, such as response style or mood (Podsakoff et al., 2012). Several strategies were employed to mitigate CMB in this analysis, including using reverse-coded items, employing different data collection methods (LinkedIn direct messages and emails) and ensuring anonymity for honest responses.

In addition to the pilot test, two *post hoc* tests for CMB also confirmed that the results are unlikely to be tainted with CMB. The first test used was Harman's one-factor test, which is the most commonly used method for detecting the presence of CMB (Jakobsen & Jensen, 2014; Podsakoff et al., 2003). Harman's single-factor test involves a factor analysis (more technically precisely, PCA in unrotated form) of the items scores of the constructs to examine whether a single factor emerges and/or the first factor (principal component) extracts a substantial amount of variability (> 50%) of the measurement item data (Kock, 2020; MacKenzie & Podsakoff, 2012). If there is a substantial amount of variance explained by a single factor, that is a reason for suspecting CMB.

Assessing CMB when formative constructs are involved, such as in this study, can be challenging since formative constructs are psychometrically distinct from traditional (reflective) constructs. This is because a formative construct does not (or by logic should not) explain the variability of its measures (items); the reverse is true of course, because formative constructs are composed of several measures (items) that collectively define/explain the construct's meaning (Jarvis et al., 2003a; Petter et al., 2007). The implication is that the measures may pass easily in Harman's one-factor test, but it may still have issues concerning CMB. To circumvent this possibility, the researcher used the “full collinearity test” advanced by Kock (2015), as the second method of checking CMB, which seems to be becoming a “must do” in PLS-SEM, when formative constructs are involved at least.

***Developing the Sampling Frame***

To develop the sampling frame, the researcher created a LinkedIn group consisting of members who are enthusiastic about LSS from around the world. Members of the group come from a variety of industries around the world representing a wide variety of industries fitting into the Australian and New Zealand Standard Industrial Classification system (ANZSIC) (Statistics, 2008; Trewin & Pink, 2006). Consequently, this LinkedIn group represented CI cultures of a wide variety of organisations that use LSS around the world. Since the participants to the survey (the LinkedIn group) were based in different regions worldwide, the researcher chose an online questionnaire platform to administer the survey. It was decided that proficiency in LSS or its constituent elements (Lean and SS, or CI) as stipulated in the ISO 18404: 2015 would serve as the primary criteria in recruiting participants for the survey. These potential participants constituted the sampling frame.

***Minimum Sample Size: Power Analysis using the Inverse Square Root Method***

A critical decision prior to quantitative data collection is to determine the minimum sample size that is required to make a statistical inference, without compromising statistical power (Cohen, 1992). In statistics, statistical power is equal to 1– Type II error, which is the probability of rejecting a false null hypothesis[13]. In practical terms or in true positivistic spirit,

---

[13] In statistical hypothesis testing schema (the null and alternative hypothesis schema) advanced by Neyman and Pearson, two types of errors are possible. The Type I (also known as the $\alpha$ error) is the probability of rejecting a true null hypothesis. The Tye II error (also known as the $\beta$ error) on the other hand is the probability of

this means the probability of detecting an effect, when in actual fact, the effect exists out there to be discovered (Cohen, 1992). The power in relation to a particular statistical analysis (e.g., multiple regression, ANOVA) depends on the sample size, the size of the true effect (population effect size), and the significance level (Type I error) used by a researcher (Chow & Chiu, 2013; Kang, 2021). All other things being the same, the larger the sample size, the larger the statistical power. The minimum sample size is defined as the sample that achieves the desired minimum statistical power, which is taken as 0.8 (80%) for basic research (Cohen, 1992; Faul et al., 2007). Meeting at least the threshold statistical power (minimum sample size) has an ethical implication for a scientist because if the sample size is too low resulting in low statistical power (high Type II error), the probability (risk) of not detecting an effect is too high, when the effect actually exists in the real world; this amounts to wasting a participant's time and wasted resources including wasting research funds. Most importantly, it can lead to false conclusions being drawn and acted upon, which can have profound consequences.

The researcher's hypothesis testing would be based on a data analytic technique known as *partial least squares structural equation modelling* (PLS-SEM), which is a piece-wise application of multiple regression analysis in a coherent manner (section 4.7.1). As an example, in the researcher's theoretical model, LSS Project Execution (response) is explained by Leadership Engagement (H3), CI culture (H6), and LSS Project Initiation (H4). Once the predictor and response scores are expressed in standardised units, the predictor-response relationship can be expressed by the multiple regression equation (4-1) shown below.

$$\text{LSS Project Execution} = \beta_1\text{*Leadership Engagement} + \beta_2\text{*CI culture} + \beta_3\text{*LSS Project Initiation} \quad (4\text{-}1)$$

If it can be demonstrated that $\beta_1 > 0$ the hypothesis $H_3$ would be supported by data. Likewise, if it can be demonstrated that $\beta_2 > 0$ and $\beta_3 > 0$ that would support $H_6$ and $H_4$ respectively. The question is "what size minimum standardised regression coefficient does the researcher require?" to argue a practically significant relationship between a predictor and a response. If the standardised regression coefficient is very small (→ 0) the power analysis would return a

failing to reject a false null hypothesis (Cohen 1992). A null hypothesis in regression analysis in relation to regression coefficients is (the default setting of any software package) "coefficient = 0". In ANOVA, "all group means are the same".

phenomenally high minimum sample size. A standardised regression coefficient that is very small (e.g., 0.10) would be of little or no practical value; this is equivalent to saying that the predictor has no consequential effect on the response. Hence the researcher used 0.15 as the threshold (lower bound value $\beta_{min}$) for a practically significant relationship (standardised regression coefficient) for her power analysis. The power analysis used by the researcher is known as the inverse square root method,[14] a method advanced by Kock & Hadaya (2018). This method is the recommended method now to determine the minimum sample size in PLS-SEM, replacing the previous method advanced by Cohen (1992), based on the F test for the regression model, based on pre-determined effect sizes (Hair et al., 2022).

It was found that the sample size required to achieve a 0.8 statistical power (hence the minimum sample size $n_{min}$) is 275 responses, if the standardised regression coefficient is 0.15, and type I error is 0.05, based on the governing equation (see equation 4-2 below) used in the inverse square root method. The researcher was able to secure more than 275 valid responses (296 to be exact) for her data analysis[15].

$$n_{min} = \left(\frac{2.486}{|\beta_{min}|}\right)^2 = \left(\frac{2.486}{|0.15|}\right)^2 = 275 \qquad (4\text{-}2)$$

Cohen's method would return a much smaller sample size. For example, for the three-predictor equation (4-1), Cohen's method requires only a sample size of 76 for an effect size of 0.15, 0.8 statistical power and 0.05 Type I error[16] (see Cohen, 1992, p. 158).

---

[14] The phrase "inverse square root" has been coned by Kock & Hadaya (2018) probably because the standard error (SE) that goes into calculation of the T statistic of a regression coefficient ($T = \beta/SE$) is inversely proportional to the square root of sample size (central limit theorem).

[15] Interestingly, if 0.10 is the minimum standardised regression coefficient a researcher is interested in, they would have to target a sample size of 618 respondents (24.86^2), which is an extremely high number for basic research.

[16] Cohen's effect size (Cohen's $f^2$) is for the whole regression model (hence depends on the $R^2$), and not for individual regression coefficients (for regression, $f^2$ = explained variation/unexplained variation = $R^2/(1- R^2)$. These are covered later (Chapter 7).

### 4.6.3 Preliminary Analysis of the Data Collected from the Full Survey

***Data Screening and Descriptive Statistics***

As a critical first step in any statistical analysis (PLS-SEM is no exception) a preliminary analysis needs to be conducted to examine data quality, the shape of the distributions of variable scores, and potential outliers. In addition, descriptive statistics (e.g., means, standard deviations, interquartile range, and correlations among variables, where relevant) on the survey participants and variables used in the model would be useful for the reader. All this is covered under preliminary analysis (section 7.4).

The hypothesis testing approach (i.e., PLS-SEM) used by the researcher does not rely on the distributional assumption of a normal distribution (bell curve) as in parametric methods such as the traditional structural equation modelling method (covariance based structural equation modelling, CB-SEM) which is based on the analysis of covariance structures of variables. However, wide departures from normality, and almost certainly the presence of outliers does affect the T values and p values of model parameters estimated via the non-parametric algorithms (typically bootstrapping) adopted in PLS-SEM (Hair et al., 2019; Monecke & Leisch, 2012).

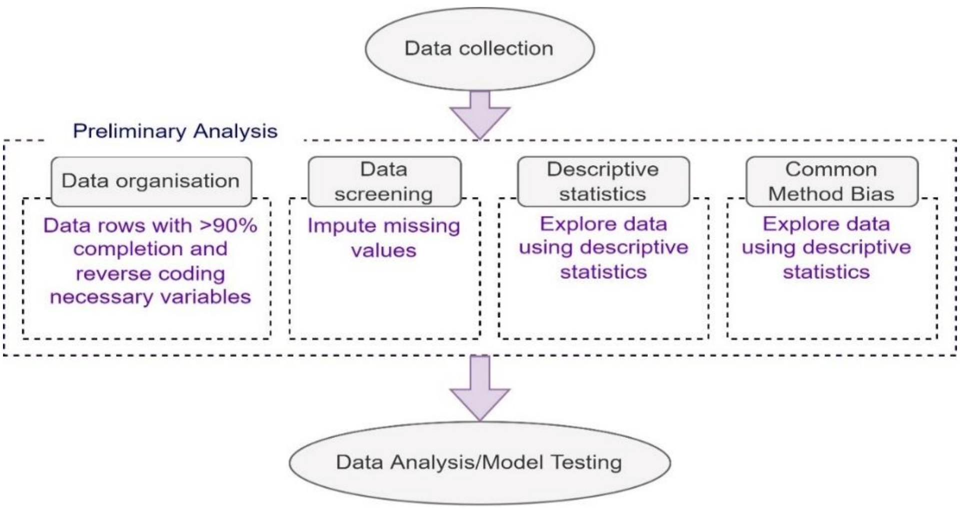



**Figure 4.14 Preliminary analysis of quantitative data**

Data screening is a fundamental step in the research process used to ensure that the data collected meet the necessary criteria for analysis. The indicator variable scores (survey responses) were screened to detect outliers, missing values, or errors in the data entry process.

As asserted by DeSimone& Harms (2017), data screening is used to ensure that survey research does not return false inter-item correlations, inter-scale correlations, scale reliability estimates, and hypothesis test results. To maximise the efficiency of the screening process the researcher employed multiple complementary screening techniques in this research:

1. Handling Missing Data: There are many methods of handling missing data. A researcher can impute missing values using a suitable imputation technique (e.g., means substitution, multiple imputation, Bayesian imputation etc.) or simply ignore the missing values and allow the software to use one of the two perennial missing value handling techniques when executing the statistical analysis: *case wise deletion* or *pair-wise deletion*. Of the 45 indicator variables, 19 contained 36 missing values, but as a proportion of the total number of observations (296*45), the proportion of missing values contained in the responses of 296 participants was only 0.27% (36/ (296*45) = 0.0027). Thus, the researcher used the most basic missing value imputation technique "means substitution" (a missing value being substituted by the mean value of the variable). The researcher argues that substituting missing values with any acceptable method is slightly better than doing nothing because the researcher's sample size (*n* = 296) is close to the minimum sample size of 275. Prior to imputing missing data, the researcher tested the datasets for patterns missing at random (MAR) or missing completely at random (MCAR) to gauge the pattern of missing data.

2. Detecting Outliers: Outliers are data points that deviate significantly from the location of most data (for normally distributed data this is the mean but for nonnormal data it is the median). For normally distributed data, 95.44% of observations are expected to be within the mean $\pm$ 2*standard deviation limit while 99.73% of observations are expected to be within the mean $\pm$ 3*standard deviation limit. It was found that there were no outliers outside the mean $\pm$ 3*standard deviation limit.

3. Multicollinearity Assessment: Multicollinearity can be assessed using tolerance or variance inflation factors (VIFs) of predictors (VIF = 1/Tolerance). Elevated levels of multicollinearity can result in instability in parameter estimates in methods such as PLS-SEM that use multiple regression approach. This is discussed further under the heading common method bias.

*Descriptive Statistics*

Researchers use descriptive statistics to summarise the data to indicate the location of data (the central tendency) as well as the dispersion of data (e.g., standard deviation or interquartile range). In addition, information on the skewedness of data (skewness) and how the tail of data compares to a bell-curve (kurtosis) can be shown either numerically or graphically (frequency distribution histogram with or without a superimposed bell curve). All this information will be shown in Chapter 7. The researcher used IBM SPSS 22 software to generate this information.

### 4.6.4 Examining Construct Validity and Reliability

*Construct Validity*

Construct validity answers the question does the construct represent the concept that it is supposed to represent? (Bollen & Lennox, 1991; Messick, 1995; Nunnally & Bernstein, 1978; Sechrest, 2005). Many forms of validity such as content validity, reliability, convergent validity, discriminant validity, factorial validity, and predictive validity is subsumed in construct validity (Messick, 1995; Nunnally et al., 1994). From a measurement perspective, construct validity refers to the degree to which a measurement scale (or index in the case of a formative construct) effectively captures and represents the underlying construct that the measurement scale is intended to measure. In PLS-SEM, construct validity is established via convergent validity and discriminant validity, in the case of a traditional construct (reflective construct) (Gefen & Straub, 2005; Hair et al., 2022).

*Convergent validity* confirms that measures converge to the construct in a correlational sense (Gefen & Straub, 2005; Hair et al., 2022). To assess convergent validity, two approaches were adopted by the researcher. First, the researcher examined the correlation between the construct and its theoretically assigned measures (items) to ensure that these correlations are strong. A strong correlation (loading) is typically regarded as a correlation exceeding 0.60 (Gefen & Straub, 2005; Hair et al., 2022). Second, the average variance extracted (AVE) of constructs was examined to ensure that these meet or exceed the 0.50 threshold prescribed by Fornell & Larcker (1981). The AVE of a construct quantifies the extent to which a construct converges to explain the variance observed in its indicators. Mathematically AVE is the mean value of the squares of correlations between the construct and its measures. This implies that AVE penalises relatively weak loadings[17].

*Discriminant validity* confirms that the measures are discrete to the point that measures belonging to a certain construct correlate with the construct more strongly than with the other constructs (Gefen et al., 2005; Henseler et al., 2015). Up until recently, Fornell-Larcker criterion (Fornell et al., 1981) was used as the standard test to examine discriminant validity when PLS-SEM or equivalent variance-based approaches have been used. The Fornell-Larcker criterion for discriminant validity requires a construct to be less strongly related with other constructs than with its own indicators, as indicated by the square root of the AVE of the construct. Henseler et al. (2015) demonstrated through simulation studies that the Fornell-Larcker criterion for discriminant validity is not as robust as the criterion that they introduced, based on heterotrait-monotrait ratio of correlations (HTMT). This criterion is known as the HTMT criterion. HTMT criterion is ideologically similar to Fornell-Larcker criterion in that both criteria examine similarity between constructs (latent variables). However, HTMT criterion has strict prescriptions of threshold values, which makes this criterion more robust than the Fornell Larcker criterion. The thresholds (maximum allowable) for HTMT ratios are 0.90, when conceptually similar constructs are involved, and 0.85 when such constructs are not involved (Henseler et al., 2015; Sarstedt et al., 2019).

*Scale reliability* refers to extent to which measures of a construct are sufficiently intercorrelated to be considered internally consistent and reliable (Gefen & Straub, 2005; Hair et al., 2022). The researcher evaluated the reliability of the constructs (to be precise, the scales of the constructs) by considering three reliability coefficients: Cronbach's alpha coefficient, composite reliability coefficient $\rho_a$, and composite reliability coefficient $\rho_c$. For basic research, Nunnally (1978) recommended a Cronbach’s alpha coefficient of 0.70 as a minimally acceptable value for basic research, although for emerging constructs, slightly lower values

[17] Supposing a construct is operationalised through N number of measures and the correlation between the construct and each measure is 0.60 the AVE of the construct would be 0.36 (N*0.6^2/N), which falls well below the 0.50 threshold. Supposing the correlation between the construct and each measure is 0.70 the AVE of the conduct would be 0.49, which is still just short of the 0.50 mark. Supposing the correlation between the construct and all but one measure is 0.80 but the correlation between a certain measure and the construct is 0.60, AVE will always be > 0.50, but the larger the N the larger the AVE (at N = 2, AVE = 0.50; at N = 3, AVE = 0.55; at N = 4, AVE = 0.57 and so forth).

may be acceptable. The 0.70 threshold has also been used as the threshold for composite reliability $\rho_a$, and composite reliability coefficient $\rho_c$ (Hair et al., 2022; Hair et al., 2019).

The reason for using as many as three reliability coefficient is as follows. Cronbach's alpha coefficient, which is the most widely used coefficient is known to provide conservative estimate for scale reliability (Hair et al., 2019). One may treat it as a lower-bound estimate of reliability. Composite reliability coefficient $\rho_c$ provides a liberal estimate of scale reliability, in the sense, the true scale reliability could be lower than $\rho_c$. Hence $\rho_c$ estimates can be treated as an upper bound estimate of scale reliability. Composite reliability coefficient $\rho_a$ on the other hand attempts to strike a balance between conservatism and liberalism.

***Validity of Formative Constructs***

Finally, none of the above validity schema are relevant for formative constructs as these constructs do not possess the psychometric properties concerning convergent validity, discriminant validity, and scale reliability (Diamantopoulos & Winklhofer, 2001; Hair et al., 2022; Jarvis et al., 2003b). In the researcher’s study, one construct (LSS Project Execution) is a formative construct. The validity of this construct was established by demonstrating that the indicators of this construct are not collinear, and that the weights of the indicators[18] of the construct are statistically significant (and if not, the loadings are > 0.50 and are statistically significant) according to the guidelines of Hair et al. (2022) and Diamantopoulos et al. (2008). More details are shown in Chapter 7 with collinearity diagnostics and statistical significance of the weights (*p* values etc).

## 4.7 Key Data Analysis Tools Used for Hypothesis Testing

This section provides an overview of the key data analysis tools used during the quantitative analysis phase of the research to test the hypotheses. The hypotheses associated with the researcher’s theorical model involved causal predictive relationships between constructs. Constructs are variables that are not directly observable unlike the variables used in natural sciences. Directly unobservable variables are known as latent variables in psychometrics

[18] The weights are used to calculate the score of the construct using standardised indicator scores.

(Bollen & Lennox, 1991; Fornell & Larcker, 1981) and the variably of such variables are observed through the variability of indicators that represent these variables. As such, the hypotheses associated with the researcher's theoretical model should best be tested using a technique that can accommodate latent variables as independent and dependent variables. This technique is generally known as structural equation modelling (SEM) (Fornell & Larcker, 1981; Hair et al., 2022). If more basic methods are used such as standard regression methods treating constructs as directly observable variables (e.g., using a single indicator to represent the construct or using the arithmetic average of the scores of indicators as the score of the construct), the statistical modelling would be less precise because the measurement error does not get represented properly in such approximations (Bollen & Lennox, 1991; Hair et al., 2022). Therefore, as far as testing the hypotheses that constitute the theoretical model is concerned, the question remains which SEM technique is best for the researcher's situation.

As mentioned earlier, the qualitative phase (case research) acted as a feeder for the quantitative phase. Looking back at the research questions, RQ1 cannot be answered fully without examining the validity of the determinants of LSS (i.e., LSS constructs as criteria and the quality performance construct as the response) and how these determinants are related to one another in explaining quality performance (i.e., testing the validity of the hypotheses H1 through to H8b as posited in Chapter 3 and Chapter 6). Hence answering RQ1 requires establishing construct validity as well as establishing statistical conclusion validity. Statistical conclusion validity is the degree to which conclusions drawn from hypothesis test tests are valid (Cook & Campbell, 1979; García-Pérez, 2012). Statistical conclusions necessitate appropriately establishing the theoretical model and evaluating the model with the appropriate statistical technique/s (García-Pérez, 2012). RQ2 cannot be answered fully without testing the validity of the construct that represents the risk-dimension. Finally, RQ3 cannot be tested without testing the goodness-of-fit of the researcher's model to data that has come from both manufacturing vs nonmanufacturing sectors (testing H9 is all about this). SEM is a very efficient method that examines construct validity and statistical conclusion simultaneously. As mentioned earlier, the researcher used the PLS-SEM technique, which becomes the more suitable technique to investigate relationships between constructs as opposed to the covariance-based approach in some situations (details in this section later). A multigroup analysis need to be conducted to test H9 to answer RQ3, and this can be accomplished as a special application of PLS-SEM.

### 4.7.1 Partial Least Square Structural Equation Modelling (PLS-SEM)

SEM combines elements of regression analysis and factor analysis. Factor analysis of observed variables examines the effectiveness of latent constructs, which are theoretical concepts that cannot be directly quantified. On the other hand, regression models examine hypotheses about the relationship between observable independent variables and the dependent variable. SEM takes care of both these aspects (Bowen & Guo, 2011; Hair et al., 2022).

In SEM, there are two primary methods: CB-SEM and PLS-SEM. The CB-SEM methodology uses structural equations to construct a theoretical covariance matrix, aiming to estimate model parameters that minimise the difference between the theoretical and observed covariance matrix (Kline et al., 2000; Zhang et al., 2021). PLS-SEM, which uses PCA-like method and multiple regression to estimate latent construct scores, iteratively estimates outer weights (weights of the indicators), loadings, and path coefficients in structural models using the least squares regression algorithm to minimise unexplained variance (Hair et al., 2022). As explained earlier, PLS-SEM does not rely on parametric assumptions to calculate the T values of model parameters. In the software package the researcher used (SmartPLS 4.0) bootstrapping is used to calculate the T values and hence the significance values (the p values) also.

While CB-SEM yields precise model estimates through covariance structure optimisation, it imposes strict requirements or constraints such as large sample size and multivariate normality, and difficulties in modelling formative constructs. PLS-SEM is more flexible as it can accommodate both reflective and formative constructs (Hair et al., 2011). Dijkstra & Henseler (2015) demonstrate that PLS-SEM can be used to analyse complex models with mediators and moderators with relatively small samples. Due to its relaxed distributional assumptions and smaller sample size requirements (Sarstedt et al., 2011), PLS-SEM has gained increasing popularity in marketing, business, and information systems research. It is important to note that the statement the researcher made in this paragraph "CB-SEM yields precise model estimates". should not be interpreted to mean that PLS-SEM provides imprecise parameter estimates to make hypothesis test results questionable. The PLS-SEM approach does become precise (consistent) when constructs have been represented by a sufficiently larger number of indicators and, the sample size happens to be sufficiently large, a condition known as "consistency at large" (Haenlein & Kaplan, 2004; Hair et al., 2011; Marcoulides et al., 2009). Hair et al. (2019), leading authors on PLS-SEM, mention nine conditions under which PLS-SEM becomes justifiable. Of these, the researcher meets five conditions (Table 4.4), thus justifying the choice of PLS-SEM data analytic technique to test her hypotheses.

**Table 4.4 The justification of the use of the PLS-SEM approach**

| Conditions that Justify PLS-SEM (Hair et al., 2019, p. 5) | Is This the Case in the Present Research? |
|---|---|
| 1. Hypothesises ought to be causal predictive. | Yes, to some extent. |
| 2. The model is complex because either there are substantial of number constructs and/or indicators and/or relationships. | Yes. Modelling interaction moderation in CEB-SEM is difficult. |
| 3. Theory extension is somewhat exploratory. | No |
| 4. One or more formative constructs are involved in the hypotheses. | Yes, very much so. There is a formative construct: PREX. |
| 5. Financial ratios and similar metrics happen to be theoretical variables. | No |
| 6. The research uses secondary data which may not represent the constructs well. | No |
| 7. The sample size is small, although PLS-SEM works very well with large samples also. | No. The researcher's sample size is not small. |
| 8. There are data distribution issues that may not meet parametric assumptions. | Yes. The data are somewhat negatively skewed. |
| 9. The need of latent variable scores for subsequent analyses. | Yes. Requires for multigroup comparison. |

In summary, SEM-PLS is considered a method of choice when one or more conditions, as shown in Table 4.4, are met. As shown in Figure 4.15, SmartPLS 4.0 software used in the study enables the researcher to carry out a systematic evaluation of data and tests on both measurement model data and structural model data. Detailed results and an accompanying discission is presented in Chapter 7.

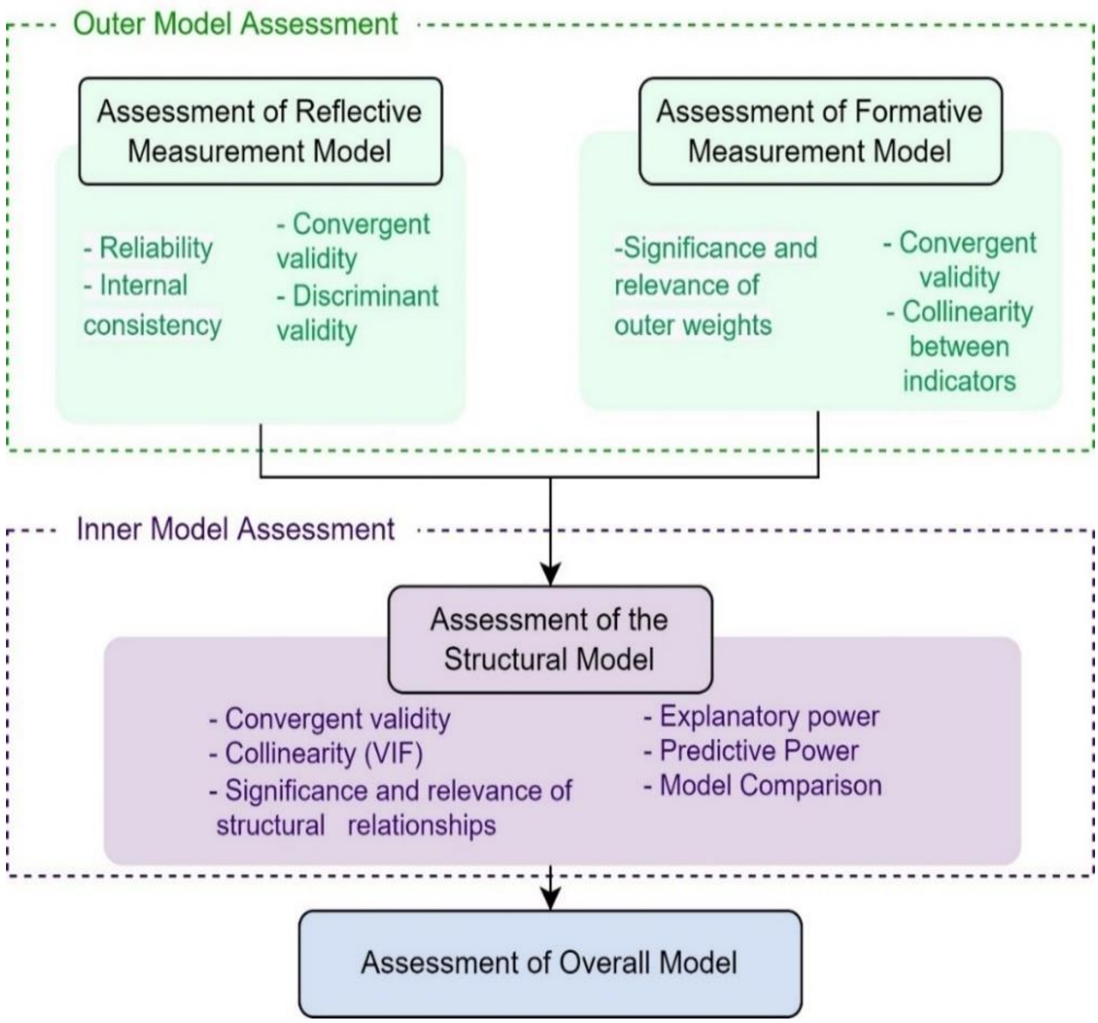



**Figure 4.15 Systematic evaluation of data (Adopted from Hair et al., 2022)**

### 4.7.2 Multigroup analysis via PLS-SEM

Of late, group comparisons have gained a great deal of popularity in a wide range of study domains, as they have proven to be a powerful tool for identifying variations within subgroups of the overall population that may not be apparent when examining the population as a whole (Carranza et al., 2020; Cheah et al., 2023; Sarstedt et al., 2011). In PLS-SEM, there are two main approaches that can be used for comparing two distinct groups of data: a parametric approach and nonparametric approach. Multigroup Analysis (MGA) is one of the nonparametric approaches in PLS-SEM that detects significant differences between groups based on bootstrap estimations (Hair et al., 2022; Matthews, 2017). Thus, MGA provides the researcher with the opportunity to test two identical models on two distinct groups at the same time (in the researcher's case, manufacturing group vs nonmanufacturing group). With the aid of this tool, the researcher can examine how well LSS aligns with the two sectors to answer the third research question RQ3 in hypothetic-deductive fashion (testing H9).

The execution of MGA follows a sequence of steps, each carefully designed to shed light on the dynamic interaction between sector categorisations and the congruence of the overall research model (Aggarwal & Kapoor, 22021; Carranza et al., 2020; Matthews, 2017). According to Matthews (2017) there are three major steps involved in MGA when PLS-SEM is used. These steps are shown in Figure 4.16.

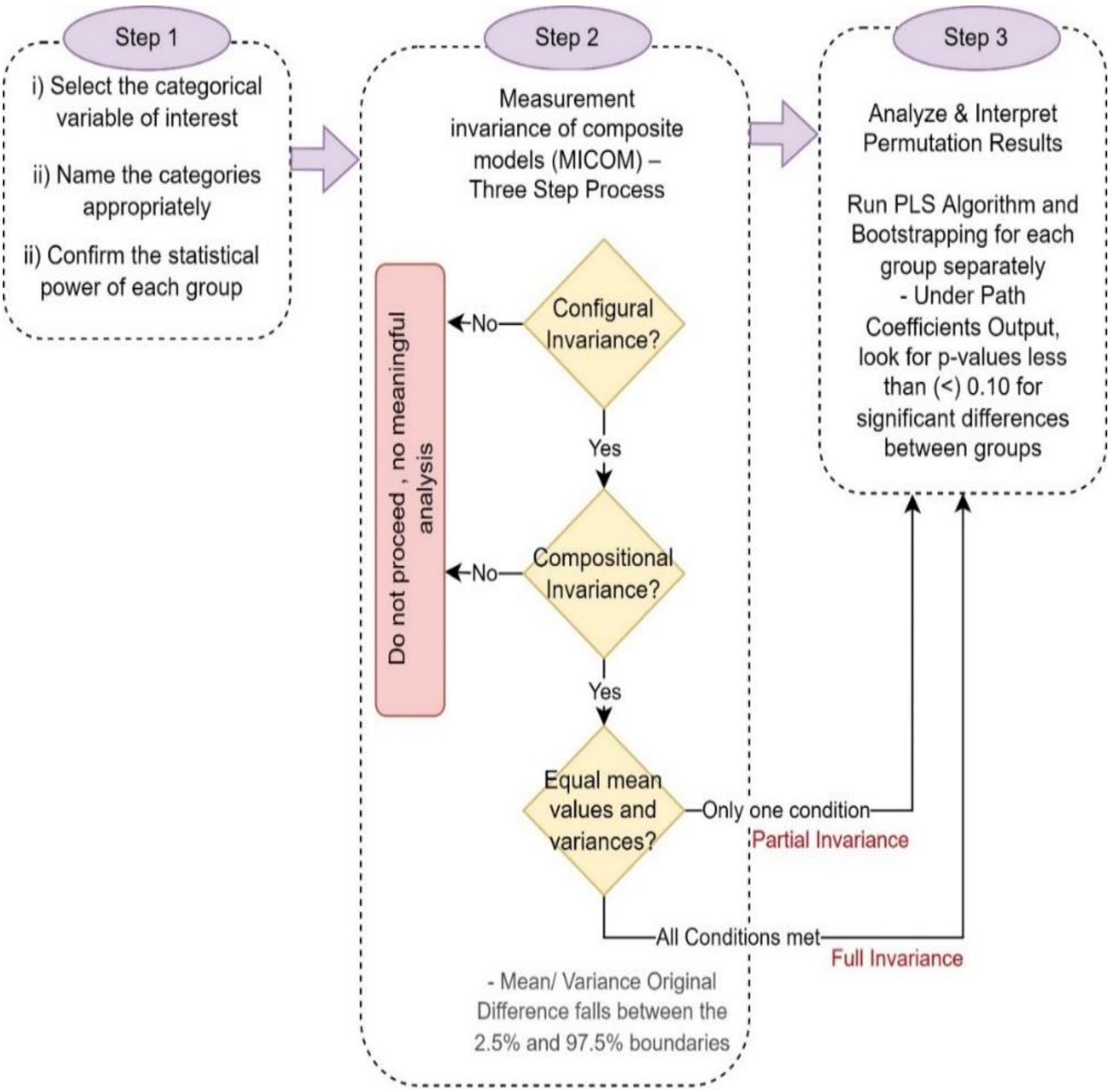



**Figure 4.16 Multigroup analysis steps**

A clear distinction between the manufacturing sector and the nonmanufacturing sector is essential at the initial stage to prepare the groundwork for a comparative analysis (the response to the industry classification question in the questionnaire is one of the most important inputs for this). There was no issue with configurational invariance (MICOM Step 1) because the same theoretical model is being used for the two groups. After confirming measurement invariance (MICOM Step 2), the researcher went on to assess the specific group differences under partial invariance (MICOM Step 3) as the equal mean and variance requirement could not be fully satisfied. The analysis under partial invariance involved comparing the estimated path coefficients, $R^2$ values, and other relevant statistics between groups to identify which paths or relationships differ significantly between groups (See Appendix E for detailed results).

## 4.8 Ethical Considerations

To conduct research involving human participants, it is imperative that ethical principles be adhered to rigorously. Researchers are entrusted with the responsibility to adhere to established ethical guidelines to ensure the welfare and rights of those involved (Coolican, 2009). As part of its ethical policy, Massey University has developed a comprehensive Code of Ethical Conduct for Research Involving Human Participants, which aims to guide researchers in their work in this regard. To ensure compliance with ethical research protocols (explicit and implicit), the researcher took the following steps:

- For this research Massey University Human Ethics committee approval was obtained to conduct the study as low-risk (a notification that it is self, and peer assessed as low risk) research (Ethics Notification – 4000020850).
- During the qualitative study, participants were given detailed information regarding the purpose of the study, the nature of the interviews, the duration, and the process for ethical approval.
- A full list of the researcher's contact information and assurances of confidentiality were provided, as well as assurances of non-disclosure of confidential or company-identifying information.
- Obtaining consent before digitally recording interviews was a priority, and sensitive questions were carefully avoided.
- The same principles of transparency were upheld in the preliminary quantitative study, which was based on the final survey. A thorough explanation of the research

topic, its purpose, the type of data and the selection methodology as well as the significance of the study was given to the participants.

- Strong emphasis was placed on the confidentiality of the data, and the anonymity of the participants was guaranteed. Participants were explicitly informed of the number of questions, the estimated time to complete the survey, as well as the incentives for participating, fostering trust and transparency among participants.
- Storing data on password protected computer and cloud server.
- A large sample was used to raise the statistical power to a desired level to ensure that nonsignificant relationships don't occur due to a small sample size. Should this happen to be the case, it would have been a shame on the researcher for wasting valuable resources, including participants' valuable time.

## 4.9 Chapter Summary

The methodology chapter is an important chapter because it outlines the "how" part of the research, which goes beyond just application of a set of methods. Methodology is the general epistemology of one's research, and the research design and methods being used become dependent parts of methodology. This chapter provided a comprehensive framework for the design and execution of research. In this section, the researcher explained the fundamental concepts that underpin the research process and discussed philosophical paradigms, which guided the research process. The researcher's philosophy is pragmatism, although another scholar may argue that the researcher's paradigm is post-positivism. This is not just because hypothetic reasoning is an essential feature in the research but also because the researcher followed the case research approach articulated by Yin (2018) and Eisenhardt (1989) to collect qualitative data. Yin (2018) and Eisenhardt (1989) are considered post-positivists because they promulgate positivist ideas such as proposition development, construct operationalisation, construct validity, and construct reliability to name some (Dubé & Paré, 2003).

With the above said, the primary focus of this chapter is research design, which followed a mixed method approach that combines qualitative and quantitative data in some logical fashion. The research used an exploratory sequential mixed method design protocol in which qualitative data collected via case research informed the quantitative (hypothetic-deductive) phase of the study by providing more information about the context of LSS implementation in practice, and a more complete understanding of how constructs manifest in the real world (this was particularly helpful in operationalising newer constructs). The chapter provided details on how the case study was conducted and the information was processed. As regards the quantitative phrase of the study, this chapter outlined the  data collection process (the survey instrument, pilot testing, sampling frame, and survey administration in full scale), the importance of the preliminary analysis (e.g. data scrutiny), the primary data analytic technique being used (PLS-SEM) and why it was used and what tests would be used within the PLS-SEM to establish several forms of validity including construct validity and scale reliability. The next chapter provides details of the qualitative data analysis and the accompanying results.

# CHAPTER 5
# QUALITATIVE DATA ANALYSIS AND RESULTS TO UNDERSTAND THE CONTEXT OF LSS

## 5.1 Introduction

Part of the contents of this chapter (section 5.5) has been published in Perera et al. (2021a). The purpose of qualitative data collection and analysis is to gain a better understanding of how LSS is practiced around the world in quality/process improvement projects and how LSS concepts manifest in the practice of LSS. In this chapter the researcher uses the term *qualitative research* to mean qualitative data collection and analysis and not the qualitative methodology. The term qualitative methodology implies an interpretivist or constructivist epistemology, which is not the researcher's epistemology.

Qualitative research is important in answering Research Question 1, because for quantitative data to confirm the determinants of LSS and how they are related to one another in predicting and explaining quality performance (Chapter 4), first and foremost, it is important to scope the researcher's conceptual model to understand its subsets through industry engagement. In this study, industry engagement means interviewing LSS experts representing a wide variety of industries. The interviews and the accompanying synthesis enabled the researcher in two ways. Firstly, the interviews and the synthesis of qualitative data enabled the researcher to better understand the context of LSS in relation to her conceptual model, which in turn leads to (some) modification of the conceptual model, where necessary[19]. Secondly, as mentioned in the previous chapter, qualitative data helped the researcher to operationalise the theoretical constructs—particularly the ones that are not very well operationally defined in the extant literature. In this chapter however, only the first aspect is covered (understanding the worldwide practice of LSS). The second aspect (construct operationalisation via case study data) is covered in the next chapter (Chapter 6). The rest of this chapter is organised as follows. Section 5.2 covers revisiting the initial conceptual model making adequate changes to the conceptual model to initiate qualitative data collection. Section 5.3 covers qualitative data

[19] A good example is, making sense out of the concept *project related contingency variables* referred to in the conceptual model (also known as the initial model in this thesis), which ended up as Project Residual Risk in the final (testable) theoretical model. Another example is qualitative data synthesis reinforcing the LSS Culture→ LSS Project Initiation link, which remained not so well-supported via the literature.

analysis results and discussion, which is the longest section of this chapter. Section 5.4 covers the summary of key findings to conclude the chapter.

## 5.2 Revisiting the Initial Conceptual Model

Chapter 3 presented the conceptual framework (reproduced as Figure 5.1 for convenience) of the study. Table 5.1 provides some literature that was used in defining the constructs. Working definitions of these constructs were provided in Chapter 3 (3.5).

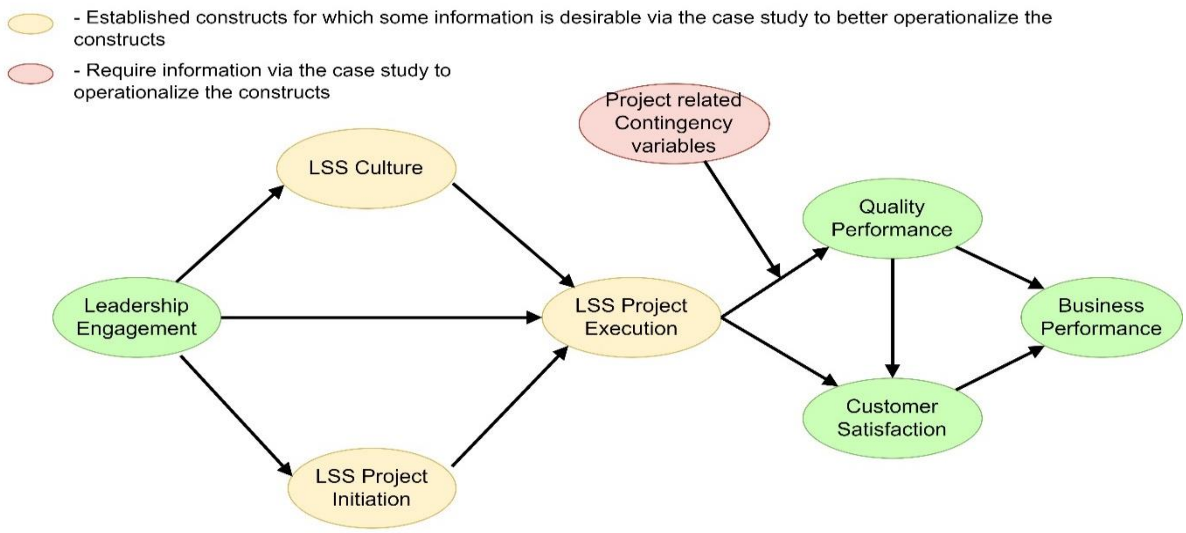



**Figure 5.1 Final conceptual model presented in section 3.5**

**Table 5.1 Key sources used to formulate theoretical constructs and current state of knowledge**

| Construct | Sources | Maturity of the Construct based on Extant Literature |
|---|---|---|
| Leadership Engagement | Adams-Robinson, 2021; Firouznia et al., 2021; Laureani and Antony, 2019; Sutherland et al., 2020, | Well established construct consistent with quality and highlighted CSFs classification |
| LSS Culture | Barcia et al., 2022; Cameron and Quinn, 2011; Featherall et al., 2019; Iyede et al., 2018; Zu et al., 2010 | This construct lacks depth, but the analysis of CSFs via ML provided the required insights |
| LSS Project Initiation | Kloppenborg et al., 2006; Söderberg, 2020; Zhang et al., 2008 | Well established construct and the analysis of CSFs via ML provided additional support |

| Construct | Sources | Maturity of the Construct based on Extant Literature |
|---|---|---|
| LSS Project Execution | Golini et al., 2016; Hellström et al., 2016; Marion et al., 2016; Ramasamy and Yusof, 2015 | Emerged from CSFs classification and need field work to shed more light on the construct |
| Project-related Contingency Variables | Benta et al., 2011; Dao et al., 2016; Loch et al., 2006 | Need fieldwork to identify specific variables |
| Quality Performance | Linderman et al., 2003; Schroeder et al., 2008; Sin et al., 2015; Zu et al., 2008 | Well established construct consistent with quality |
| Customer Satisfaction | Linderman et al., 2003; Schroeder et al., 2008; Sin et al., 2015; Zu et al., 2008 | Well established construct consistent with quality |
| Business Performance | Linderman et al., 2003; Schroeder et al., 2008; Sin et al., 2015; Zu et al., 2008 | Well established construct consistent with quality |

### 5.2.1 Modifying the Conceptual Model to Facilitate Construct Operationalisation

The initial model (Figure 5.1) is developed treating LSS as an organisational theory on operational performance (as more specifically quality performance) and business performance. Based on the initial model, the execution of a Lean SS project results in Quality Performance and Customer Satisfaction, which in turn results in Business Performance. Consequently, there are three outcome constructs in the initial model. Quality Performance and Customer Satisfaction are intermediate outcomes while Business Results is the outcome. Quality Performance and Customer Satisfaction are strongly interrelated (Schroeder et al., 2008; Snee & Hoerl, 2007; Sodhi et al., 2020). In addition, when the unit of analysis is changed to a specific LSS project. Business Performance becomes ambiguous. Consequently, the three outcomes were merged into a single construct, which was named "LSS Performance", as shown in Figure 5.2.

Interview responses revealed that the well-known project contingency variable *project complexity* is considered in the project initiation phase and the other well-known project contingencies *project uncertainty* and *project ambiguity* are partially taken to account as part of risk planning in the project initiation stage. Therefore, it was clear that the only uncertainty that remained was the project's residual risk, which could only be identified after the fact (after project implementation). See section 5.5.5 and Figure 5.15. While project-related residual risk is a well stablished concept in project management literature (Pich et al., 2002; Usman Tariq, 2013), fieldwork was needed to better understand how residual risk manifests in LSS Projects.

The interviews also revealed that LSS Culture should be labelled as CI Culture to better reflect the current practice of LSS (section 6.4.2).

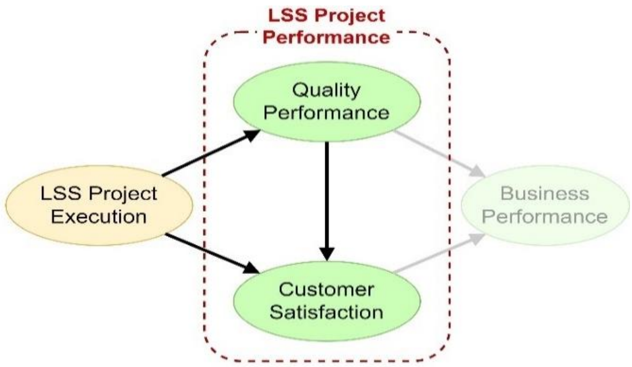



**Figure 5.2 Initial model with construct establishment status in the literature**

Figure 5.3 shows the research model used in conducting the qualitative research based on the questions shown in the interview questionnaire (Appendix B). This model changed somewhat (e.g., Project related contingency variables became Residual Risk and a link from CI Culture to LSS Project Initiation was established) after the qualitative data analysis phase. Note that the labels "PART C:1, Part B: 1&2" and so forth refer to the question numbers in the interview questionnaire.

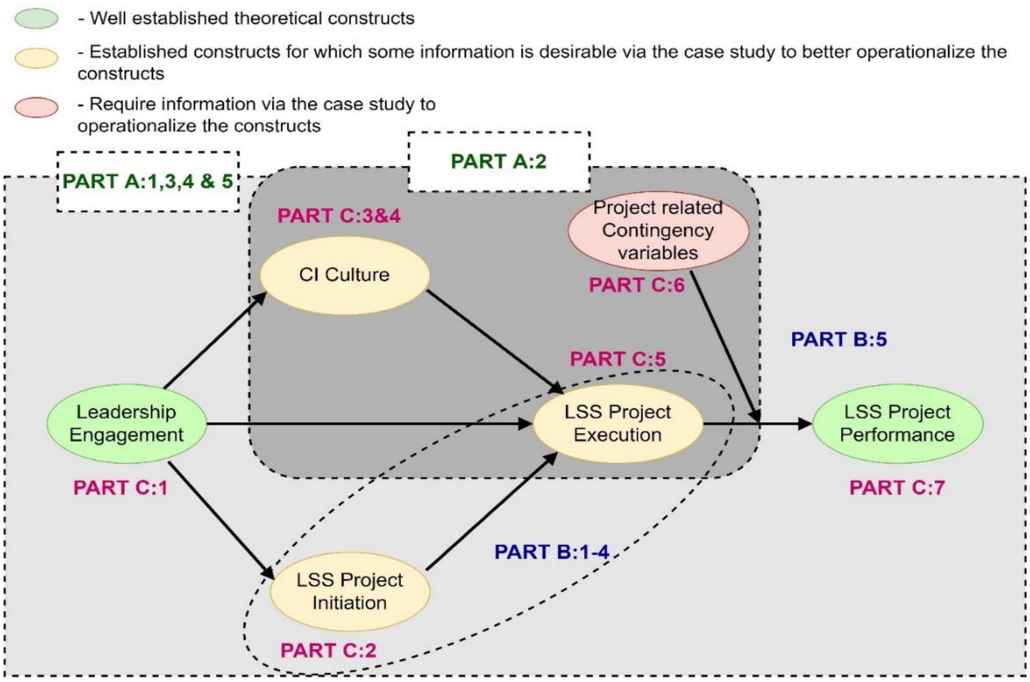
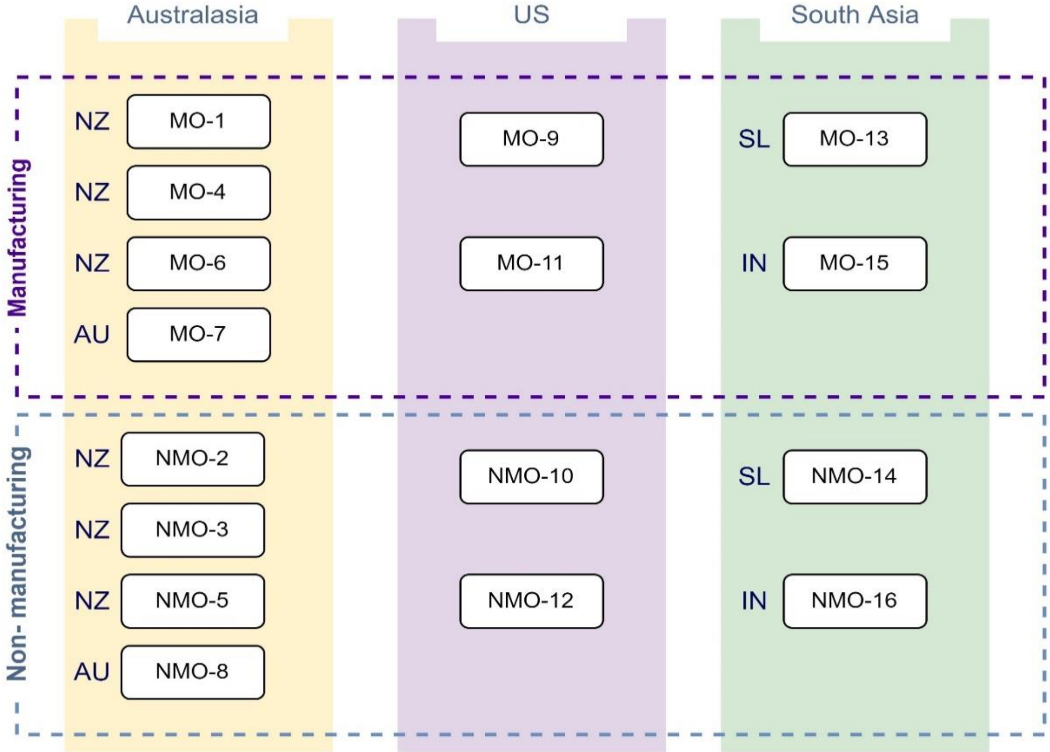



**Figure 5.3 Research model used for the qualitative research**

## 5.3 Results and Discussion

**The 16 cases selected for the qualitative analysis are summarised and illustrated in Figure 5.4, more details of the participants/organisations are included in** Table 4.2.




*Country Interview Sequence is New Zealand→(NZ) , Australia→(AU), United States of America→ (US), Sri Lanka→(SL), India→(IN)

*MO means a manufacturing organisation; NMO means a non-manufacturing organisation.

**Figure 5.4 Case selection summary**

A comprehensive exploration of the prominent themes that surfaced from the qualitative responses collected via part B of the interview questionnaire is presented in this section. As mentioned at the beginning of this chapter some parts of this section were published in Perera et al. (2021a); the article was published in the special issue of the International Journal of Lean SS on LSS practices in the Australasian region. This article compared LSS practices in Australasia with those in the US, which as treated as the control group (from a qualitative data analytic sense); the US was treated as a control group because SS originated in the US and its metamorphosis into LSS also took place in the US to some extent and there are well known LSS organisations in that country.

### 5.3.1 Definition of an LSS Project

The researcher found that organisations adopt LSS in diverse ways, which prompted the informants to define LSS differently (Table 5.2). Many respondents (all but MO-7 and MO-9) provided multiple definitions resulting in eight major definitions. Some participants viewed LSS as an integral part of the organisation's culture on pursuing perfection, emphasising its integration into the organisation rather than to specific projects. This perspective aligns with the CI philosophy, portraying LSS as an integral part of the organisation's DNA rather than a mere project-based approach (Definition 1 and 4 in Table 5.2). The following are a few quotes from the participants.

"We do not use the term SS or LSS to define our projects; we place them all improvement projects under the umbrella of continuous improvement." (NMO-8)

"In my view, LSS does not emphasise a project-based approach; LSS is a culture that an organisation embraces. I have seen many organisations and consultants fail when they believe that implementing LSS is about rolling out projects." (NMO-5)

The above opinions that came from the two Australasian participants from the nonmanufacturing sector challenges the time-honoured quality/process improvement notion of Juran, who in 1954 famously said "all improvement happens project by project and in no other way" (Van Vliet, 2012). Unsurprisingly, most respondents viewed LSS through a project-based lens, emphasising its systematic application (do what is needed to overcome the specific improvement problem being handled) to specific improvement efforts. This vindicates selection of an LSS project as the unit of analysis for this research. It was evident that respondents consistently associate LSS with a systematic and rigorous approach in which application of tools (in a favourable CI culture/climate) comes into the forefront to achieve operational excellence, as illustrated by the definitions 3 and 7. Additionally, the integration of Lean Thinking with SS tools, as outlined in definition 6, was also found to be a common definition. The fusion of Lean Thinking and SS tools was often described as evidence of LSS's holistic nature, in which the reduction of waste and the optimisation of the process are intertwined. Further, aligning with definition 8 some respondents highlighted the importance of senior management sponsorship. The view was that LSS implementation requires leadership commitment and support. Aside from that, LSS was viewed by some as a cost reduction tool, emphasising its tangible impact on an organisation's business performance. Overall, the respondents valued LSS for its flexibility, allowing organisations to capitalise on the strengths of both Lean and SS.

**Table 5.2 Definition of LSS by respondents**

| | Definition | Participants | MO | NMO |
|---|---|---|---|---|
| 1 | A CI culture that uses LSS tools rather a project | MO-6, NMO-8, MO-15, NMO-16 | 2 | 2 |
| 2 | A project that has TQM and Lean tools | NMO-3 | - | 1 |
| 3 | A project that uses LSS tools systematically | MO-1, NMO2, MO-4, NMO-8, MO-11, NMO-12, MO-13, NMO-14 | 4 | 4 |
| 4 | A CI project that uses LSS tools | NMO-5, NMO-8, NMO-16 | - | 3 |
| 5 | A cost reduction process that uses LSS tools | MO-7, MO-9, MO-15 | 3 | - |
| 6 | Lean Thinking infused with SS tools | MO-1, MO-4, NMO-5, MO-6, MO-13, MO-15 | 5 | 1 |
| 7 | A project that combines Lean and SS components | NMO-2, NMO-3, NMO-10, MO-11, NMO-14, NMO-16 | 1 | 5 |
| 8 | Project that has the senior management sponsorship and aims at reducing wastes or variation systematically | NMO-10, MO-11 | 1 | 1 |

Notes:

O1 − O6 were participants from Australasia.

O9-O12 were participants from the United States

O13, O16 were participants from South Asia

MO: a manufacturing organisation, NMO: a nonmanufacturing organisation

From Table 5.2, it is evident that there is no uniform understanding of LSS across a sector, as different perspectives arise from both manufacturing organisations (MO) and nonmanufacturing organisations (NMO). However, most participants from manufacturing organisations emphasised the systematic use of LSS tools (e.g., MO-1, MO-4, MO-11, etc.). Based on the DMAIC framework of LSS, which originated in manufacturing, this tool-based focus (e.g., value stream mapping, the seven basic tools/B7 tools, failure modes and effects analysis, five-why analysis, design of experiments) is quite common (Raval et al., 2018b; Uluskan, 2019). It was clear from the definitions provided by MOs that data-driven, structured improvement efforts are critical to optimising processes and reducing variability within manufacturing environments. Conversely, NMOs generally had a variety of definitions that are more diverse in nature. Although one NMO participant introduced TQM tools in defining LSS (NMO-3), there are overlaps between the NMO perspectives and MO perspectives, such as the integration of Lean and SS components.

All the above said, overall, the evidence suggests that the scope of LSS can be viewed differently between manufacturing and nonmanufacturing sectors; this industry specificity could potentially pose challenges in the use of improvement tools and techniques. The researcher classified the LSS definitions into three groupings based common definitions highlighted in each sector as well as the most generalisable definition for LSS (Figure 5.5). One probable reason for the definitional discrepancy seems to be the nonmanufacturing participants' inability to distinguish between the methodology and tools (and techniques). The manufacturing participants in the main correctly distinguished between the methodology (Lean principles driven by DMAIC) and tools but their nonmanufacturing counterparts do not seem to have done so. For example, the nonmanufacturing notion of the application of lean tools and SS tools within a CI culture does not conflict with the manufacturing notion of LSS but the nonmanufacturing notion does not seem to recognise that there is a so-called driving engine (DMAIC) behind the application of the tools as in the manufacturing notion.

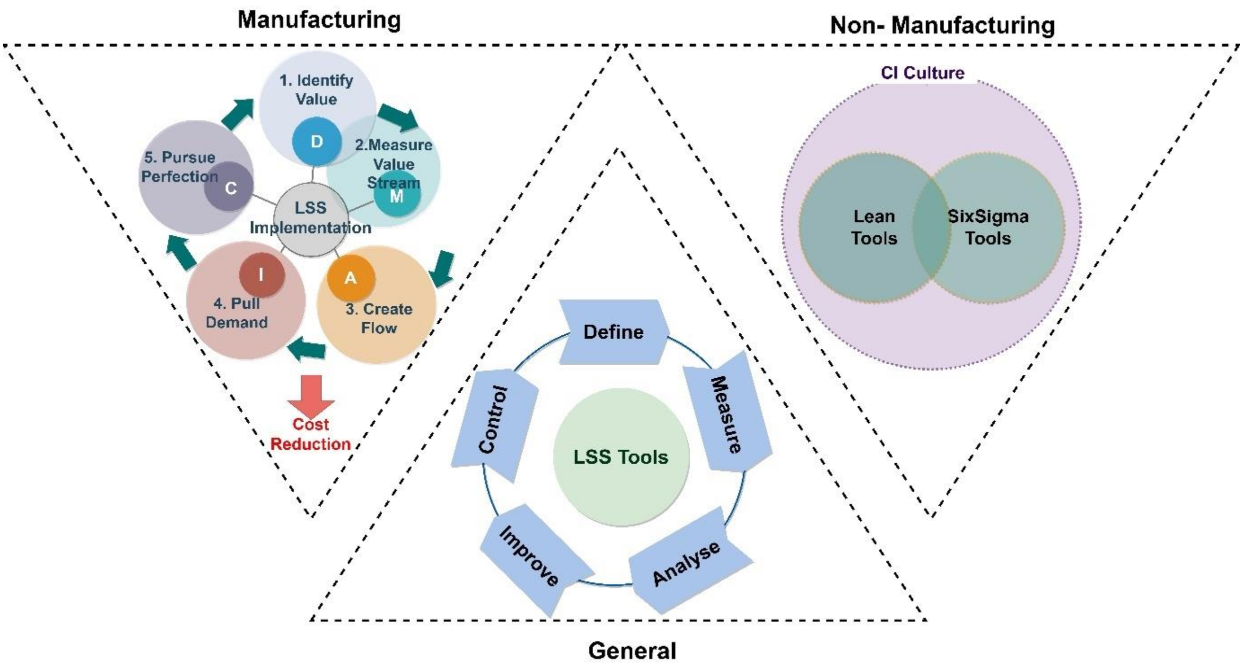



**Figure 5.5 Common definitions of LSS**

### 5.3.2 The Synergy Between Lean and LSS Components

The second interview question of Part B of the questionnaire was "if you were to partition an LSS project into Lean and SS components, which components would you consider as Lean and which components would you consider SS?" One answer to this question was:

"Lean (components) helps to get the basic process flow and mind-set of continuous improvement clearing off any wastes or inefficiencies in the process. SS (components) comes with powerful statistical tools to improve the process further and to sustain the results. Since SS directly focus on customers, it is important to have both components for better results." (MO-1)

Based on the analysis of the responses to question 2 (Table 5.3), it was found that the Lean and SS components within an LSS project can be classified based on three considerations or approaches: the focus of the goals of Lean (waste reduction) and SS (variation reduction); the application and complexity of the project (low hanging fruit with lean and advanced data driven problems remaining with SS); usage of tools (Figure 5.6). The results (Table 5.4) suggest that there is no difference between manufacturing and nonmanufacturing (or across regions) in partitioning of the components of Lean and SS components within an LSS project.

The third interview question (in part B of the questionnaire) was: "how can lean and SS components complement each other in LSS projects?" The analysis of the responses revealed that Lean and SS components share many common tools, although they take different pathways to achieve the same goal of customer focus. This finding is also in line with the third approach (usage of tools) to partitioning the elements of Lean and SS within an LSS project (Table 5.3).

**Table 5.3 Approaches to partitioning Lean and SS components in an LSS project.**

| Approach | Participants |
|---|---|
| Lean focuses on eliminating waste, while SS aims to reduce process variation | NMO-5, MO-6, NMO-10, MO-11, MO-13 |
| Lean helps with quick wins whereas SS provides an in-depth analysis | MO-1, NMO-3, MO-4, NMO-8, NMO-12, NMO-14, MO-15 |
| Lean and SS have their unique tools but both tools may be crucial for some LSS projects. | NMO-2, MO-7, MO-9, NMO-16 |

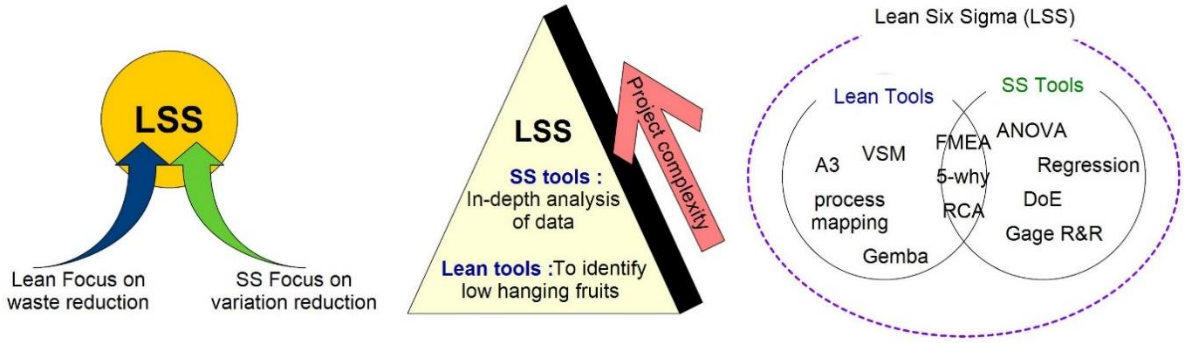



**Figure 5.6 Three approaches to partition components in an LSS project**

### 5.3.3 LSS Structure

In an LSS culture, CI is embraced by all members of an organisation, regardless of their level, as well as the application of LSS Thinking across the organisation. As a result, organisational culture has a significant impact on promoting a competitive advantage (Barney, 1991; Knapp, 2015). Thus, LSS culture should be incorporated into the organisational culture to ensure sustainability (Douglas P & J., 2000; Knapp, 2015; Laureani & Antony, 2019; Sony et al., 2020a). Despite organisational cultural convictions, the SS knowledge framework embedded in LSS philosophy provides a clear definition of LSS cultures, using a Parallel meso-structure (PMS) reflecting reporting structures, roles, and responsibilities (Schroeder et al. 2008). In a PMS (see Figure 5.7), the project champion is the top node in the hierarchy who facilitates the LSS project while supporting and guiding the team in project selection, defining project charters, and recruiting other roles such as Black Belts (BB) under a Master black belt (MBB) (Knapp, 2015; Laureani & Antony, 2019; Snee & Hoerl, 2007).

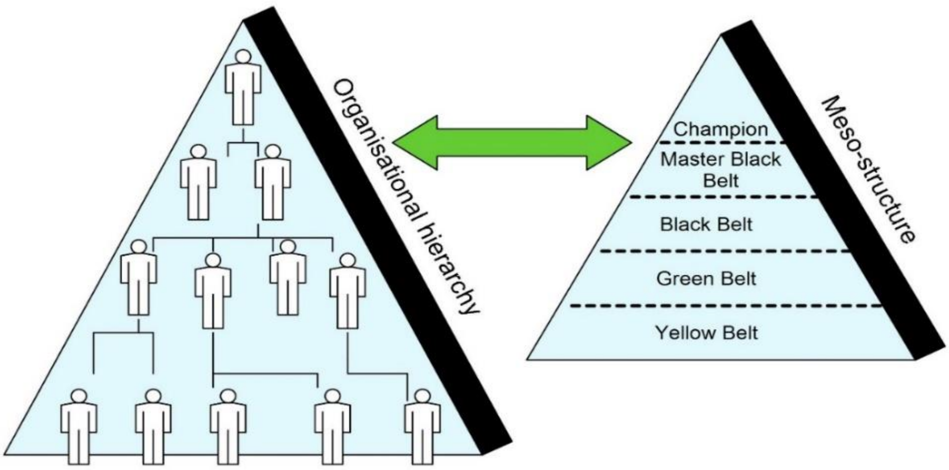



**Figure 5.7 Parallel meso-structure**

The fourth question in Part B was a long one: LSS projects draw team members from many functional units (e.g., operations, R&D, inbound logistics, and even sales and marking if need be). Under these circumstances, how does the LSS reporting structure look like, given that specialists also report to their line manager, and each project has a specific goal to achieve within a short period of time? I want to understand the key elements of the LSS stricture. Table 5.4 highlights that several facets (attributes) emerge in relation to the LSS reporting structure. First is the reporting structure. From the results of the case research, it is evident that there are a wide variety of ways in which LSS aligns with existing hierarchical reporting structures. Since some organisations follow tier-to-tier reporting structures, as well as aligned with a PMS hierarchy, it is evident that LSS can adapt to an organisation's existing structure. Interestingly, even respondents from the US mentioned that they previously always used the belt system and the reporting structure in LSS projects, but today, the belt system is not always used in LSS projects. Based on the findings from the case study, the researcher concludes that in general, LSS projects are implemented through departmental management systems coordinated by project teams.

**Table 5.4 Different facets of the LSS structure**

| Facet/Attribute | Nature of Practice | Participants in alignment |
|---|---|---|
| Reporting Structure itself | Does not follow the same hierarchical reporting structure as the PMS, but there exists a tier-to-tier reporting structure | MO-1, NMO-2, NMO-3, MO-4, NMO-5, MO-6, MO-7, NMO-8, MO-9, NMO-12, MO-13, NMO-14, NMO-16 |
| | In accordance with the reporting responsibilities in the PMS, but not strictly following that structure in some projects | NMO-10, MO-11, MO-15 |
| Training | Following the belt system, conduct in-house training program for the training of Yellow Belts (YB) and Green Belts (GB), and an external training program for Black Belts (BB) and Master Black Belts (MBB) | MO-1, NMO-2, NMO-3, MO-4, NMO-5, MO-6, MO-7, NMO-8, MO-9, NMO-12, MO-13, NMO-16 |
| | Provides training programs that are based on the belt system. Most trainings, including BB, are designed within the organisation. Trainings in MBB are conducted externally only | MO-9, MO-11, NMO-14, MO-15 |
| Inclusion of a BB or a MBB for an LSS project | The inclusion of a BB or a MBB is not a requirement at any stage of an LSS project, as the improvement teams or process owners execute the project on their own. BBs or MBBs only facilitate and guide the project. | MO-1, NMO-2, NMO-3, MO-4, MO-6, MO-7, NMO-8, MO-9, NMO-10, NMO-12, MO-13, NMO-16 |

| Facet/Attribute | Nature of Practice | Participants in alignment |
|---|---|---|
| | A BB or MBB is an essential component of any LSS because their expertise and guidance make a significant difference. | NMO-5, MO-11, NMO-14, MO-15 |
| Management | Managed through departments and executed as a team with varying degrees of inter-departmental collaboration | MO-1, NMO-2, NMO-3, MO-4, NMO-5, MO-6, MO-7, NMO-8, MO-9, NMO-10, MO-11, NMO-12, MO-13, NMO-14, MO-15, NMO-16 |
| Usage of external expertise | In general, external consultants are employed for training purposes, but internal teams lead the actual process improvement initiatives. | MO-1, NMO-2, MO-4, MO-6, MO-7, NMO-8, MO-9, NMO-12, MO-13, NMO-14, NMO-16 |
| | Involve external consultants to guide projects and authorise them to direct projects within the organisation with the help of an internal team | NMO-3, NMO-5, MO-15 |

The second facet shown in Table 5.4 "the training approach" seems to be a salient feature of an LSS structure. The responses suggested that LSS training approaches may differ between organisations, which makes sense because the training needs to be geared to meet the improvement needs faced by an organisation. For example, in general, there is more scope for applying statistical techniques in manufacturing than in services. Although all case research participants have adopted the belt system for LSS training, the extent to which these programs are conducted in-house or externally seem to differ from one organisation to another. Some organisations conduct extensive in-house training programs for the lower echelon specialists (YB and GB) and external training for higher echelon specialists (BBs and MBBs), while others primarily rely on internal training, with external training limited to specific cases. This variation suggests flexibility in tailoring LSS training to organisational needs.

The third facet shown in Table 5.4 is on the inclusion of BBs or MBBs in LSS projects. In some cases, BBs or MBBs were not required for an LSS project, emphasising that improvement teams and process owners carry out projects independently or in some cases BBs or MBBs serving as facilitators in the LSS project. In contrast, other organisations consider having BBs or MBBs serve as essential, because of the contributions these higher echelon specialists can make. This makes benefit/cost sense in most cases. Supposing the defects rate that can be achieved in an LSS project without a BB (or MBB) is 2700 parts per million (Cpk = 1.0 under no process drift) and a inclusion of a BB (or MBB) can reduce the defects rate to just 64 parts per million (Cpk = 1.33 under no process drift), for most products, the marginal benefit of including a BB (or a MBB) would easily outweigh the marginal cost of including them. It is interesting to note that 50% of the respondents who insisted on having a BB or MBB in the

LSS project team represented nonmanufacturing (NMO-5 and NMO-14 as opposed to MO-11 and MO-15). The fourth facet shown in Table 5.4 is on the management of the project. It became clear from the results that the degree of inter-departmental collaboration in LSS projects vary. In the collaboration spectrum some organisations could be placed at the low end while some could be placed at the opposite end (high) and some in-between. This may be symptomatic of the culture of the organisation. A clan (collaborative) culture would value collaboration more than say an adhocracy (create) culture (Cameron & Quinn, 2011).

Finally, fourth facet shown in Table 5.5 is on the usage of external expertise. Here again, differences existed across organisations. Many organisations seem to have employed external consultants primarily for training purposes because internal teams have been tasked the responsibility of process improvement. In contrast, some organisations seem to have employed external consultants not only for training, but also for guiding and directing projects, working alongside internal teams. Neither MOs nor NMOs have shown a consistent pattern of employing hierarchical structures or PMSs in all the facets being considered in an LSS structure. structure. Figure 5.8 demonstrates how an LSS structure can exist in an organisation without the use of belt systems and how LSS projects can exist within the LSS structure across both contexts (i.e., with the belt system vs without the belt system).

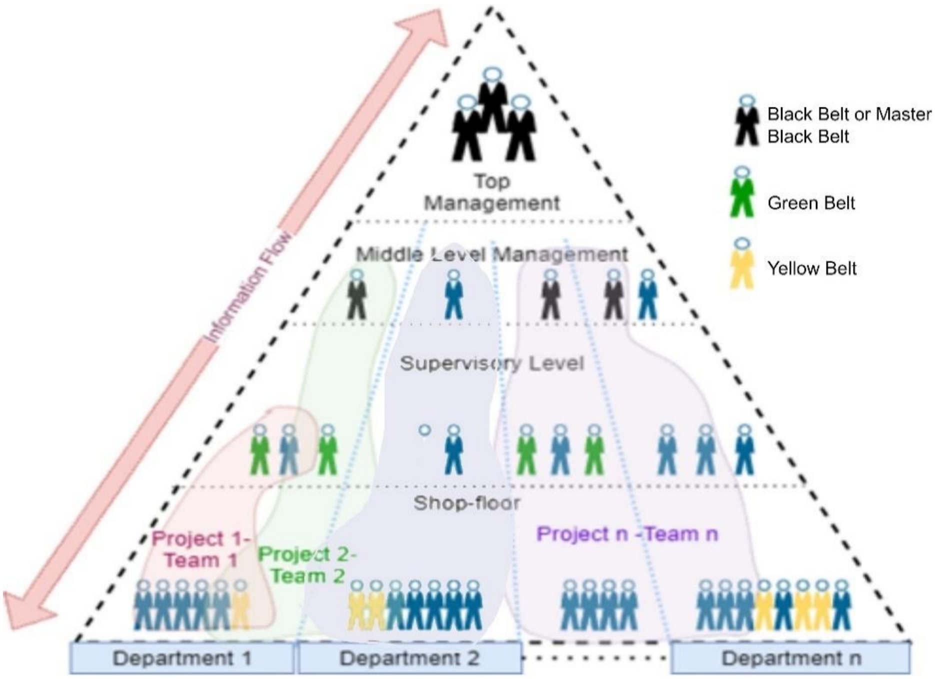



**Figure 5.8 General LSS Structure**

### 5.3.4 LSS Maturity and Comparison of DMAIC with PDCA

From the 18 participating organisations among the Anglo regions, the most experienced LSS organisation happened to be a US organisation (manufacturing) with 31 years of LSS implementation experience. The least experienced LSS organisation happened to be a New Zealand organisation (nonmanufacturing) with just five years of LSS implementation experience (Table 4.2). A notable difference that appeared between US organisations and organisations from other regions (including South Asia) was the overall LSS implementation maturity in favour of the US organisations. Furthermore, the evidence suggested that LSS is a relatively innovative approach for the nonmanufacturing industry across regions, compared to the manufacturing industry. Interestingly, all nine manufacturing organisations in the regions have at least of 13 years of experience in LSS. More importantly, the length of time in practice demonstrates that there was a compelling reason to sustain the LSS philosophy for such an extended period in US organisations.

The second part of question 1 in Part B of the questionnaire was: In what ways does an LSS project differ from standard continuous improvement initiative such as PDCA (Plan-Do-Check-Act)? Academia may question why the researcher wanted to know the difference between the PDCA cycle and DMAIC, given that PDCA versus DMAIC (plus other similar approaches) have been well covered in the literature (e.g., Kumar Phanden *et al.*, 2022; Snee, 2007). The researcher inlcuded that question because she wanted to know how the two approaches are being interpreted at practice level. The practice level understanding of DMAIC is very important in developing the operational definitions for some of the LSS constructs (more specifically the construct "LSS Execution"). The researcher now provides the requisite analysis on PDCA versus DMAIC.

The analysis of the responses provided compelling evidence that practitioners in both manufacturing and nonmanufacturing contexts perceive PDCA and DMAIC as distinct problem-solving methods. A few statements are provided as examples.

"PDCA is a process improvement cycle or a methodology; it is not necessarily a tool. LSS is a tool or a methodology. They both specifically improve processes." (MO-1)

"PDCA is the root of DMAIC. PDCA can be used as a tool for basic problem solving whereas DMAIC applies for advanced analysis using SS tools such as DOE." (NMO-12)

The response of the first participant (MO-1) is interesting to say the least. They seem to view PDCA as a methodology because of its generalisability. Virtually any improvement effort can go for ever, as there is no end to improvement, as advocated by quality gurus such as Shewhart and Deming, who advanced the iterative cycles approach to quality improvement (Mauléon & Bergman, 2009; Summers, 2010). The first participant (18 years of LSS experience under their belt) viewed LSS as a tool but sometimes as a (problem solving) methodology. What the participant seems to imply is if LSS is applied for quick wins it is a tool (e.g., the application of value stream mapping to reduce waste) but if LSS is applied as a structured problem-solving approach (DMAIC) it is a methodology. The twelfth participant's response (MO-12) was wittier. They avoided getting trapped in terms such as methodology and tools. In philosophy, methodology (general epistemology) is always placed at a higher level than tools and techniques. Based on the responses received to the question PDCA vs DMAIC and the subsequent synthesis resulted in Figure 5.9 resulted, which attempts to differentiate DMAIC from PDCA, from a practice perspective.

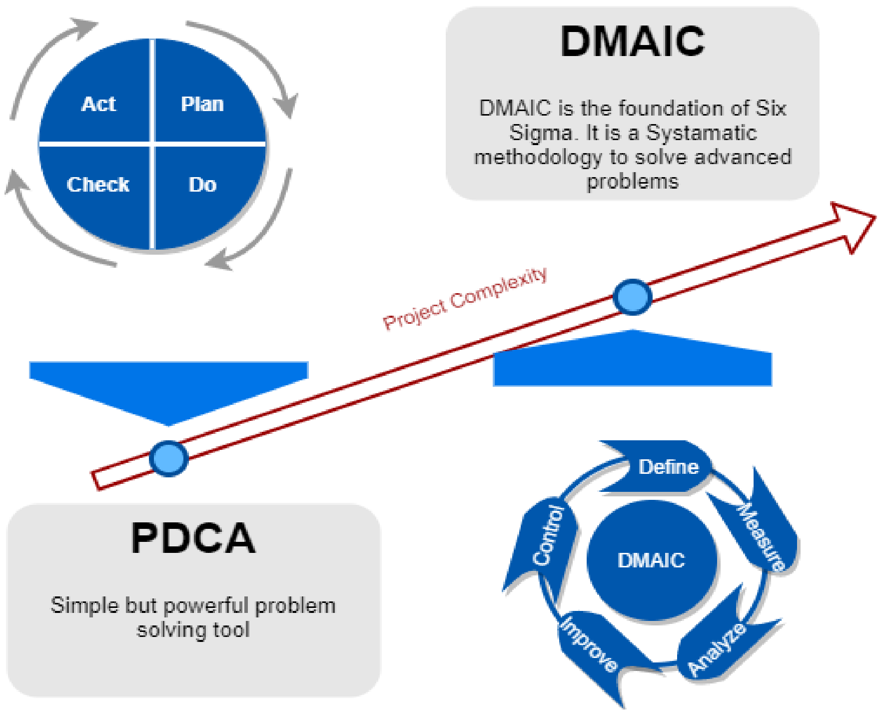



**Figure 5.9 Differentiating PDCA and DMAIC**

In general, the notion "PDCA is a simple problem-solving approach whereas DMAIC is an advanced (and systematic) approach" appeared as a common answer. Likewise, the notion "the root of DMAIC is the PDCA" also appeared to be a common response, although none of the participants (not even MOr2) went on to compare the two approaches head-to-head (Figure 5.9). The analysis to the Responses to the last three questions (questions 5 to 7) of the questionnaire (Part B) is given in Sections 5.3.5 to 5.3.7. The three questions are:

> Q5: Think about your most recent LSS project. What led you/your organisation to select this project? Sub-question: Please describe to me as clearly as possible, how LSS projects get initiated.
>
> Q6: How did you ensure that this project is the right project at the right time to deliver the right results? Sub-question: What are the key drivers of successful project initiation?
>
> Q7: In your experience on all the LSS projects in which you had a hand on, how challenging was it to sustain improvements that your company initially attained through the LSS project?

The above questions lead to examining LSS practices in depth. The researcher divided the practice of LSS into three sections: project initiation, project execution and sustaining the results.

### 5.3.5 LSS Project Initiation

Project initiation is a crucial stage of a successful implementation of an LSS project (Antony et al., 2018; Galli, 2018). The project initiation process in an LSS project involves several steps. The first step is to identify the need for improvement or find a quality or productivity gap. This can be done by listening to the customer or listening to the business and identifying whether the project goals and objectives align with the business strategy. Thereafter, the impact of the issue either on the process or the stakeholders (either internal or external) needs to be assessed (Albliwi et al., 2015; Ben Ruben et al., 2017; Chakravorty & Hales, 2016; Näslund & Mi Dahlgaard Park, 2013). As a result of the responses to the questions regarding the initiation of

LSS projects (Q5 and Q6), the researcher was able to establish a general structure for initiation of LSS projects, resulting in a more appropriate selection of LSS projects. This was a practice that was widespread in all three regions in prioritising a LSS project (Figure 5.10).

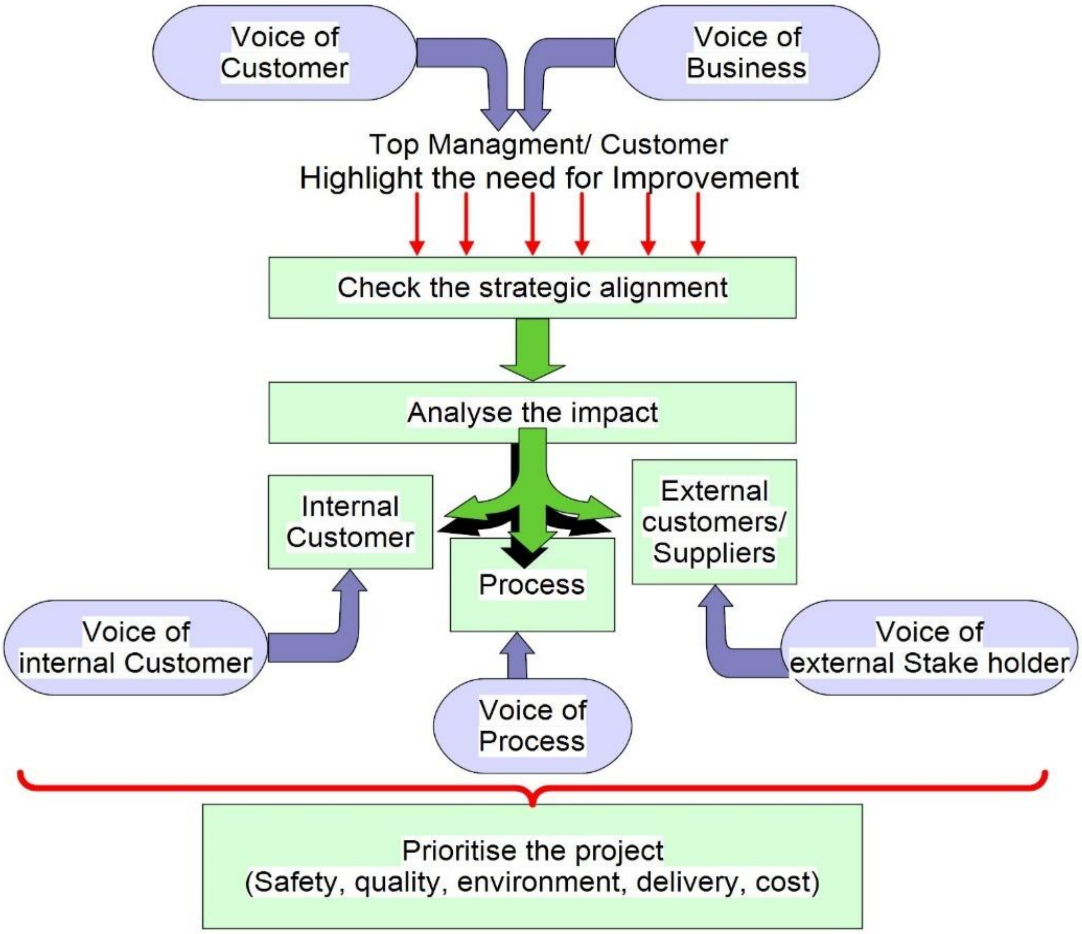



**Figure 5.10 How LSS project selection manifests manifests within an LSS project initiation, based on the responses**

As part of a systemic approach to improving performance, selecting the right project is important for successful LSS implementation (Holmes et al., 2015; Sony et al., 2020a; Sreedharan et al., 2019). Also, a thorough analysis is required before project initiation to minimise risks during project execution (Hadi-Vencheh & Yousefi, 2018; Usman Tariq, 2013).

The synthesis of responses to Q5 and Q6 resulted in two ways of LSS project initiation: the bottom-up approach and top-down approach (Table 5.5). Key quotes from participants in relation to the two questions are given below.

"Implementing an LSS project can be driven by internal and external customers. Even a change in top management can get us moving in a new direction. The need for improvement on the most recent project came from the end customer who was concerned about the lead time." (MO-1)

"We conduct daily problem-solving sessions with the team guided by the CI team. The process owners then present their problems and conducts a 5-why analysis together with the team. If a quick fix is what needed to solve the problem, a problem-card (a card with simple 5-why analysis displayed on the shop floor) will be used and write down the set of actions discussed to solve the problem. However, if the problem needs an in-depth analysis and more support, the process owner leads a separate problem-solving session or can escalate to an A3 with the support from the CI team. And these findings can initiate an LSS project led by CI team, or the problem and the solution can even be part of a bigger project." (MO-13)

"There are some projects that are top-down, like ministry projects, and some that are driven by the customer or by audit findings. When it comes to project initiation, we give the priority to our process owners; sometimes it is a team of process owners" (NMO-2)

"We did a Value Stream Map of the entire organisation from start to finish, and I was the one who was facilitating; so, I had members from the senior executive team and the operational leaders, directors. We then identified improvement opportunities." (MO-7)

**Table 5.5 LSS project selection**

| Selection Method | Nature of Practice | Participants in alignment |
|---|---|---|
| Bottom-up project selection | The LSS team identifies a potential area for improvement and selects an LSS project accordingly. The project then needs to be approved by top management. Identification of the opportunity for improvement may come from the internal or external customer. | MO-1, NMO-2, NMO-5, MO-6, MO-7, NMO-8, MO-9, NMO-12, MO-13, NMO-14, MO-15, NMO-16 |
| Top-down project selection | The project selection is by top management in accordance with business needs and then passed on to the LSS team for implementation. A business need that leads to an LSS project will be determined by the end customer in this case. | NMO-3, MO-4, MO-7, NMO-10, MO-11, |

Responses confirmed the known fact that it is important to recognise that customer's voice as it plays a significant role in both project selection methods. As far as identifying the project need and selecting the LSS project are concerned, it seemed likely that both MOs and NMOs would employ both approaches, depending on the scope of the project.

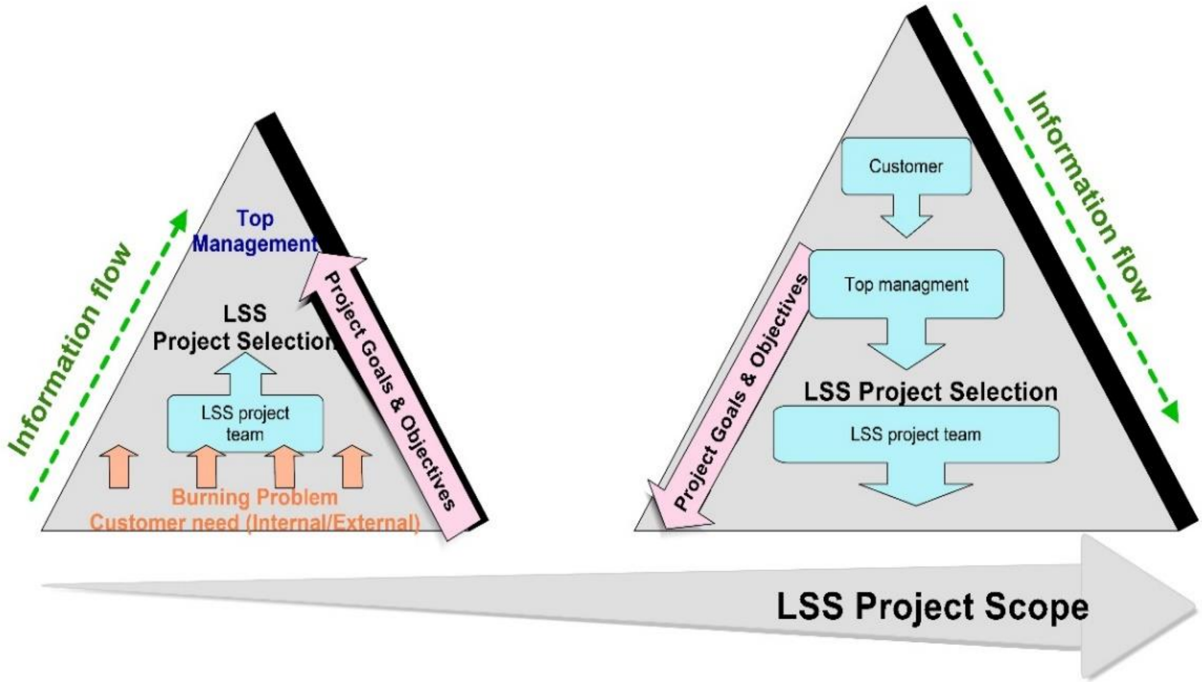



**Figure 5.11 The two most common methods for selecting an LSS project**

The responses received in relation to selecting the right project (this is in response to Q6) provided a deep understanding of the practices adopted by the participating organisations. The results suggested that both manufacturing and nonmanufacturing organisations participating in the case study prioritise and select projects in a similar manner to ensure that the right project is chosen at the right time. Regardless of where the need for improvement arises (top management or internal customer), the goal of any LSS project should be to align project's goals and objectives with the organisation's business objectives. Figure 5.11 depicts how different elements of the bottom-up and top-down approaches align to achieve a project's goals and objectives. Upon identifying the improvement need, the project owners in the organisations belonging to the case study prioritise the project, based on its alignment with organisational strategy, the impact of improvement (e.g., projected return on investment), and the level of customer focus. Consequently, the selected project will be driven by the process owners, who may seek external expertise support, if they are lacking in expertise or knowledge. Some of the key quotes on project selection are mentioned below.

"Once the senior leadership highlight a gap, the managerial level will team up with the bottom level, re-analyse the impact of the project, and check realigning process of business objectives. In some cases, we need to come up with projects according to the needs of our customers where we play the role of suppliers to align with their business needs." (NMO-2)

With the operation and senior leadership involved sessions to put everything in perspective, we put all[20] into a priority matrix, which gives us an overall idea of what projects we should do. That's how we funnel down the top five or the most suitable projects." (MO-7)

"The project was prioritised by senior leadership and required to support business strategy." (NMO-8)

"Once we've identified the potential LSS projects, we assess them based on a set of predefined criteria. Factors like the impact on our key performance indicators, resource requirements, and alignment with our strategic goals and the alignment with the current business plan are crucial in this evaluation. We often employ data-driven techniques, such as root cause analysis and Pareto charts, to prioritise projects objectively." (MO-13)

Figure 5.12 graphically presents how an LSS project is prioritised or selected by aligning project goals and objectives with the organisation's strategic goals and objectives.

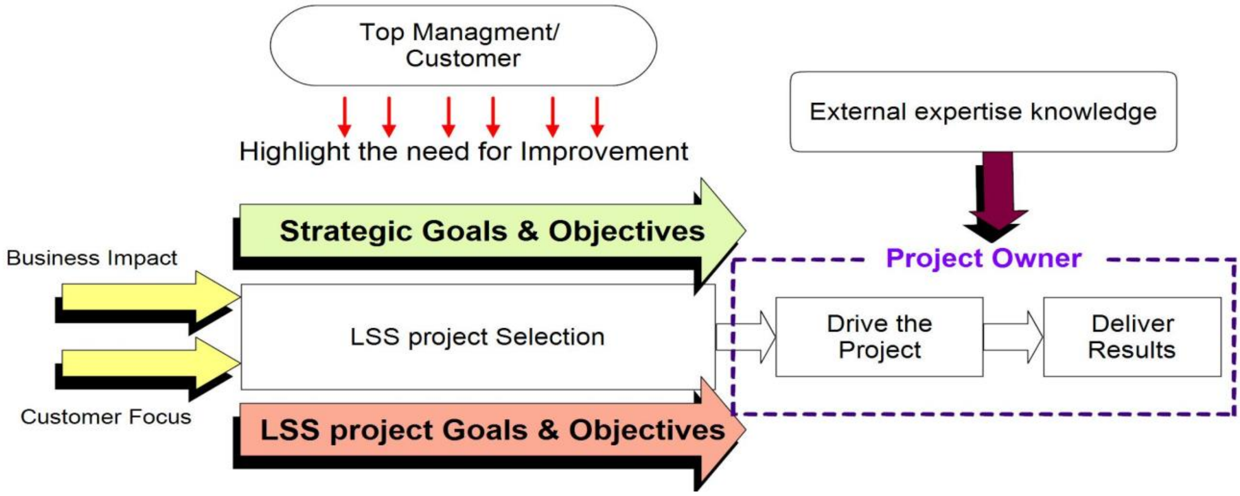



**Figure 5.12 General method for Project prioritisation**

[20] Here the word "all" means all the criteria and choices that go into the priority matrix.

Now the attention is focused on the sub-questions of Q5 and Q6:

Q5 sub-question: Please describe to me as clearly as possible, how LSS projects get initiated.

Q6 sub-question: What are the key drivers of successful project initiation?

The responses of the participants highlighted a common theme regardless of the region the organisations operate or their industry. The participants' responses supported the researcher's proposition that the LSS project gets initiated with the support of leaders; the researcher also speculated that the CI culture within the organisation could support (aid) successful project initiation. The quantitative data corroborated the researcher's speculation (quotations follow).

"In our organisation, every LSS project begins with strong leadership support and involvement. It's a clear signal that the leadership values continuous improvement, and this sets the tone for the entire project."(MO-11)

"I've seen that in various industries and regions, when there's a culture of continuous improvement, LSS project initiation tends to be smoother. It's like everyone understands the importance of these projects, and leaders actively encourage them." (NMO-3)

These findings helped in shaping the project initiation construct and the relationship between other constructs (Specifically between CI culture and LSS Project Initiation). It was highlighted that exemplary leadership motivates employees to generate and implement innovative ideas by sponsoring and motivating them. Additionally, a clear definition of the problem from the perspective of the customer also emerged as a common theme. LSS projects are oriented toward solving specific customer-centric problems, and this aligns with the foundational principle of LSS. Therefore, the researcher concluded that an effective project initiation relies on a strong sponsor and strong team engagement (see Figure 5.13). This aligns with the idea that LSS projects require all levels of support and commitment. A participant also mentioned the importance of mutual learning, where employees can benefit from learning something new, enhancing their skills and contributing to their well-being. Quotations that support the content covered in the above chapter are given below.

"Having a leader who sponsors and champions our innovative initiatives makes all the difference. It's not just about their words; it's about their actions that show they're genuinely invested in our success. This kind of leadership encourages us to excel and bring our creative ideas to life." (MO-13)

"Customers don't always express their issues in technical terms. They tell us what's bothering them, and it's our job to translate that into a clear problem statement. It's like deciphering a code sometimes, but it's absolutely essential." (MO-7)

"The purpose of LSS projects in our organisation is not only to improve processes; it's to foster mutual learning as well. It is beneficial to our organisation as well as our personal and professional growth that team members are able to acquire new skills, whether they are statistical analysis or problem-solving techniques." (MO-13)

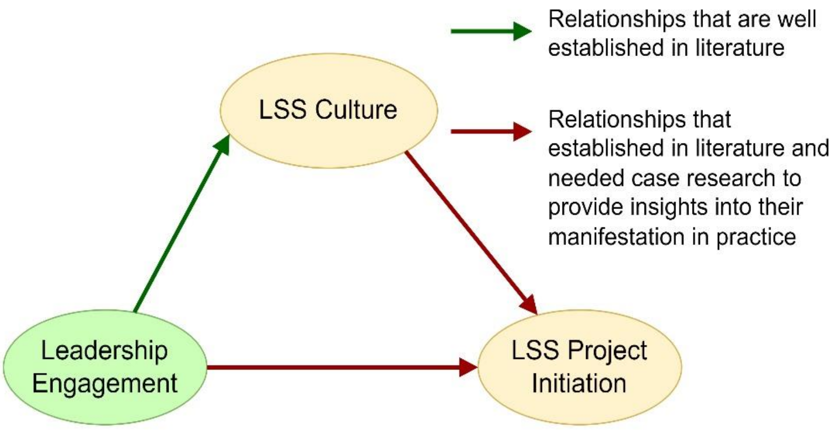



**Figure 5.13 Project initiation drivers**

Moreover, respondents were consistent in their opinion that effective project initiation is crucial for mitigating risks and minimising adverse impacts of project-related contingencies. In their opinion, organisations are better able to identify/anticipate potential risks and uncertainties early in the project by establishing a robust project initiation process, which enables them to formulate proactive risk management strategies. Among these activities are conducting thorough feasibility studies, defining clear objectives, and ensuring that the project aligns with the organisation's strategic objectives. Moreover, an effective project initiation depends on the engagement and communication of stakeholders. This is to ensure that all relevant parties have a common understanding with respect to the project's expectations and potential difficulties.

By addressing these critical aspects during initiation, organisations can reduce the likelihood of unforeseen obstacles, enhance project planning, and ultimately increase the project's chances of success, while minimising the negative impact of any unforeseen contingencies that may arise during project execution. The following are a few key statements made by respondents.

"I believe most of the risks can be foreseen through a proper analysis of the project scope and requirements. If we blindly step into a project without fulfilling the initial requirements of assessments, it is like jumping off a cliff without understanding the depth of the water below". (MO-4)

“Generally, our team assesses the risks that are manageable and visible before executing any plan, so I think it's a crucial step.” (NMO-10)

“Planning for risk is now a very fundamental concept in quality. Even ISO 9001 emphases this. Yes, even if anticipate risk at the planning stage, there will always be some risk remaining that we did not anticipate. This is the very nature of any project”. (MO-15)

Therefore, the moderating factor in the model has been refined and given as the Project residual risk. As shown in **Error! Reference source not found.** Project residual risk is the risk remaining after major risks have been mitigated. Residual risk can be calculated using residual probability and residual impact.

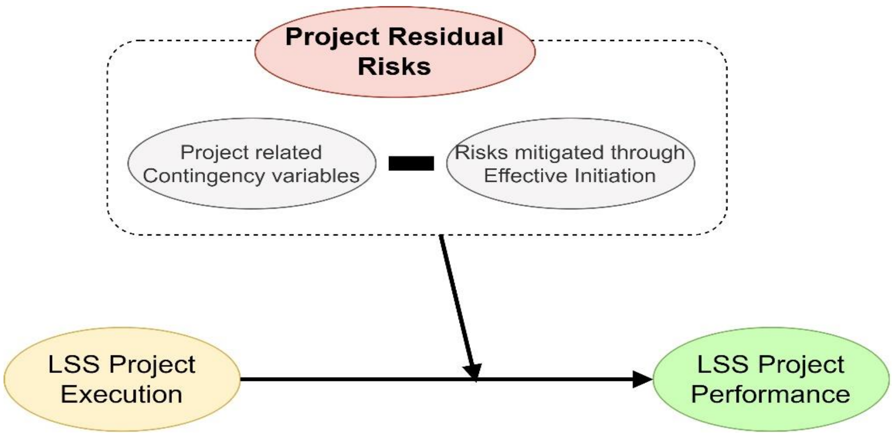



**Figure 5.14 Moderating effect of project residual risks**

Since the residual risk would only be identified after the fact (after completing the DMAIC process), due care needs to be taken by the researcher in operationalising the construct "Residual risks". A proximal variable for the construct would be a viable solution.

### 5.3.6 LSS Project Execution

To ensure the success of a particular LSS project, the management of the organisation needs to take sufficient care to assess the work culture, processes, and readiness before sanctioning execution (Hill et al., 2017; Sreedharan & Sunder M, 2018; Yadav et al., 2017). The results highlight that Australasian organisations focus on setting the CI culture or the mind-set rather than focusing on tools, during the execution. In contrast, US organisations focus on systematic reviewing and following a structured method using LSS tools during the execution stage. The focus of the South Asian organisations seems to be similar to that of Australasian organisations. This finding further confirms the fact that the definition of LSS projects used by each region is distinguishable from each other (this was discussed under the LSS project definition). Listed below are some key statements made by respondents regarding the execution of LSS.

"Culture is the most influential factor in execution. In order to execute any project successfully, you must have a CI mindset. In a CI culture, the fear of failure has been tempered, and the employees have been trained to achieve success gradually. Once CI culture is established, all that is left is for the leadership and ownership to be good sponsors for the resources to be allocated to projects and to guide the employees" (MO-1)

"We don't let people work in isolation. For each project, we keep project managers, and they follow the project management steps. We'll decompose a task into the tangible levels and as individuals." (MO-9)

"During each phase, we should find out what we did and how it was processed. Then analyse the results. During execution, we engage more as the top management, which motivates teams. A continuous review is needed to ensure the project is continuing in the right direction, whether there are difficulties in the project at every stage. DMAIC processes can be well executed when the right toolset is used." (NMO-10)

"We value teamwork, and our culture supports fostering of ideas for continual improvement, no matter how useful they end up with. If you ask me what is the most import factor for implementing LSS projects, I'd say it is our culture. Yes, leadership support is important, but what is the LSS organisation that does not have leadership support? All have" (with a sarcastic smile) (NMO-14)

Participants' responses provide insight into the key factors contributing to the success of LSS projects in various organisations. A continuous improvement mindset can only be fostered by an organisation's culture and Leadership Engagement, emphasised by the participants. It is stressed that regular project reviews, accountability, clarity regarding project outcomes, and structured project management are essential components of successful project completion. Additionally, participants emphasise the importance of cross-functional collaboration, top management involvement, and team collaboration in LSS implementation. It is evident from these insights that LSS project execution has many distinct aspects and that there are various stages of implementation across organisations, highlighting the diversity of factors that contribute to the success of LSS projects. Based on the findings of the case study on the implementation of LSS projects, no refinements were required to the initial model.

### 5.3.7 Sustaining LSS Results

***The final question in the interview questionnaire (in Part B) is as follows:***

Q7: In your experience on all the LSS projects in which you had a hand on, how challenging was it to sustain improvements that your company initially attained through the LSS project?
In order to benefit from a CI methodology such as LSS, both manufacturing and nonmanufacturing organisations make the assumption that people possess an inherent desire for quality and value; however, the top management must ensure that the improvement project designed to deliver the required quality/value will pay off in the long run (Su et al., 2014; Sundar et al., 2014). Although LSS may be an invaluable method/approach for organisations to succeed in today's competitive markets, the ability to sustain the results is determined by several factors, as the participants highlighted. Thus, on the strength of responses to Q7, the researcher investigated how challenging it was to sustain improvements that were initially attained through an LSS project. Figure 5.15 depicts the forces that were found to impact on sustaining the results of an LSS project, based on the responses and force-field analogy (Lewin,

1975) involving driving forces and restraining forces the researcher identified. The researcher identified seven key driving forces and eight restraining forces. It appeared that respondents from both manufacturing and nonmanufacturing sectors had similar views about the driving forces and restraining factors of sustaining LSS results. Some respondents emphasised the importance of resource allocation and the process owner's buy-in as highly important driving forces, while others highlighted the importance of leadership buy-in. All respondents agreed that a reward and recognition system (non-monitory) does motivate the associates to actively participate in the implementation of the LSS. The most frequently cited restraining factor among participants in nonmanufacturing industries was government policy and regulation. This implies that a conducive government policy framework is necessary to facilitate CI adoption in nonmanufacturing organisations. In any case the researcher’s model shown Figure 5.15 could be used as a tool to know how to balance the driving forces and restraining forces to keep the improvement in equilibrium than downward spiralling.

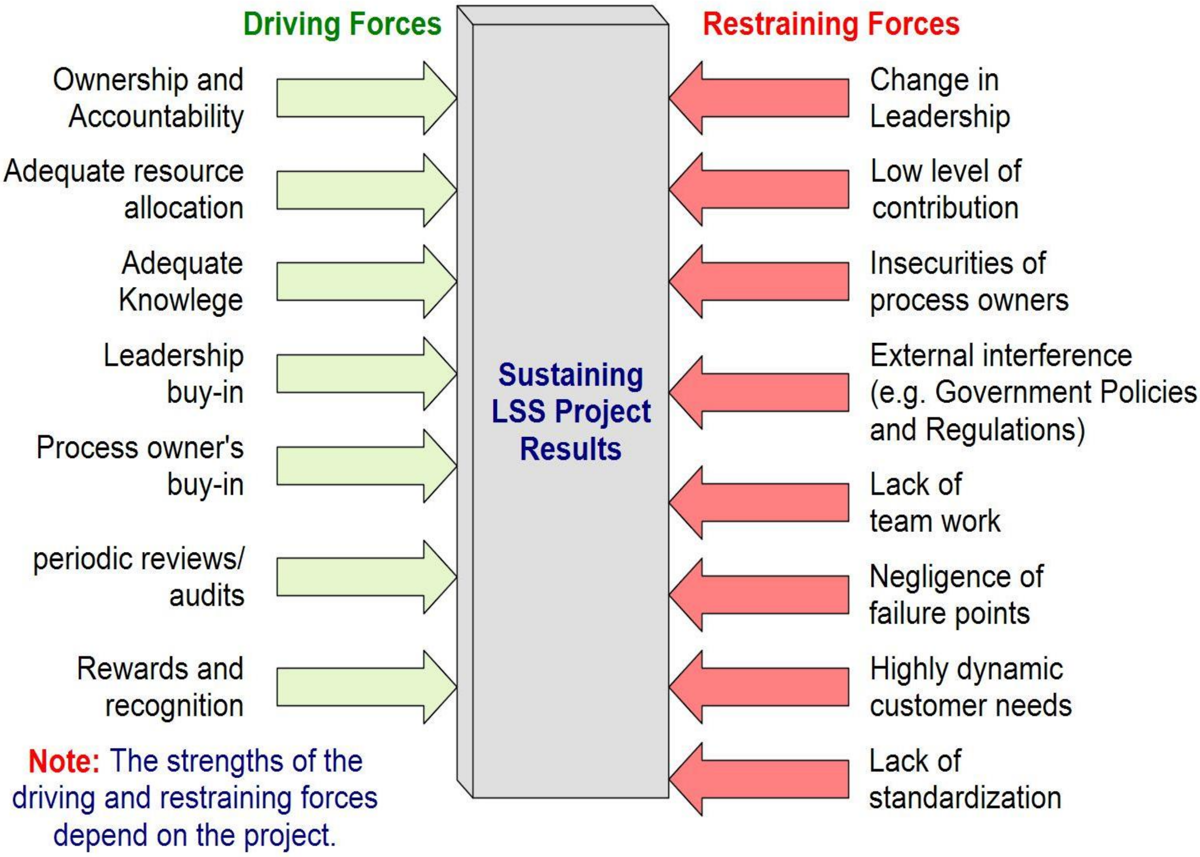



**Figure 5.15 Forces impacting on sustaining the results of an LSS project**

## 5.4 Summary and Conclusion

The qualitative data collected from the 16 case study participants helped the researcher in two broad ways. Firstly, the qualitative data and the resulting synthesis helped the researcher to understand the context of LSS project initiation and execution, and thereby refine the model where necessary. Secondly, the qualitative data and the resulting synthesis helped the researcher in providing a more complete operationalisation of her constructs; representing constructs through valid operationalisation is a necessary requirement for empirical testing of the model with large sample quantitative data. However, because the scope of the qualitative study is wide, the results and the synthesis on construct operationalisation are not covered in this chapter. These are covered in the next chapter (Chapter 6). Thus, the main purpose of this chapter is to present the qualitative data analysis and results related to the context of LSS project initiation and execution. The key findings can be summarised as follows:

1. The definition of an LSS project differ between manufacturing and nonmanufacturing. There is a tendency in nonmanufacturing to define an LSS as any project that uses Lean tools and SS tools. DMAIC as the driving engine of LSS (in other words, the LSS methodology) was not very prominent in nonmanufacturing.

2. Manufacturing seems to incorporate Lean principles and the SS methodology (DMAIC) in a more profound way than nonmanufacturing; cost reduction and bringing superior value to their customer seems to be motive of implementing an LSS project in manufacturing. The lesson to learn as far as the researcher is concerned is that she should be careful when she is operationalising the construct "LSS Project Initiation" because a more generalisable conceptualisation is required for that construct. It was found that a common definition that can be analytically generalised across both manufacturing and nonmanufacturing was found to be: "LSS project is a project that uses Lean thinking with SS tools".

3. As far as the LSS structure is concerned, the reporting structures, training approaches, and inclusion of higher echelon experts (BBs and MBBs) as implementers of LSS projects vary. It was found that LSS projects can be conducted within a variety of organisational structures, aligned with existing hierarchical reporting structures (the

functional structure), or using a more flexible reporting system. Furthermore, the flexibility of LSS allows organisations to design customised training programs based on internal and external factors.

4. The opinion among participants was divided as to whether BBs and MBBs should be included in LSS projects by default. Some organisations viewed them as essential (because of their expertise), while other organisations viewed them more as facilitators, rather than experts leading the improvement intervention. The parallel meso structure referred in the literature by leading scholars (e.g., Schroeder et al., 2008; Zu et al., 2008) was not clearly visible in most organisations.

5. Project related contingences are considered at the planning stage of an LSS project but there would always be a residual risk that remains, as in any project. As such, this residual risk would be the factor that moderates the LSS project outcomes. The residual risk would only be identified after the fact (after completing the DMAIC process). The lesson to learn as far as the researcher is concerned is that she should be careful when she is operationalising the construct "Project Residual Risks". A proximal variable for project residual risk would be a viable solution.

6. Sustaining improvement gains is challenging, but the fieldwork enabled the researcher to generate a model (based on force-field analysis) that can sustains the gains.

The next chapter makes use of the data collected through Part C of the interview questionnaire to operationalise the constructs to make the researcher's final model empirically testable.

# CHAPTER 6
# DEVELOPMENT OF HYPOTHESES AND SURVEY INSTRUMENT

## 6.1 Introduction

This chapter presents two important aspects on the quantitative phase of the study. First, this chapter presents the empirically testable (falsifiable) hypotheses that collectively represent the researcher's theoretical model (sections 6.2 and 6.3). Next, this chapter shows how the constructs of the hypotheses were operationalised using extant literature as well as case study data (section 6.4). These construct operationalisations have been presented in the survey instrument (Appendix D) as statements for which agreement of the respondents was sought in a 1-7 Likert scale, as stated in Chapter 4.

## 6.2 Presenting the Hypotheses in the Final Model

The initial conceptual model that formed the foundation of the researcher's theory was presented in Chapter 3. The modified conceptual model based on insights gained through qualitative research was presented in Chapter 5. The modified conceptual model attempts to explain how LSS project performance is caused by Leadership Engagement through a specific causal mechanism. In particular, the following were accomplished via refinement of the conceptual model through field research:

1. *Merging three overlapping constructs to LSS Project Performance*
   In the initial model, LSS project results were represented by three overlapping constructs: Quality Performance, Customer Satisfaction, and Business Performance. When designing the case research the researcher identified that there is a significant correlation between quality performance and customer satisfaction, which was also supported in the literature (Schroeder et al., 2008; Snee & Hoerl, 2007; Sodhi et al., 2020) and once the researcher decided (during the case research stage) that the unit of analysis of her study should be an LSS project (unit of analysis) implemented by an organisation, Business Performance became a redundant, thus resulting in a single outcome construct, which was aptly named as LSS Performance (see Chapter 5, section 5.2.3).

2. *Crystallising the CI Culture → LSS Project Initiation relationship*

   To better reflect the LSS practices, the researcher found that the culture of the organisation needs to be modified as CI Culture to represent the CI mindset of organisations that implement LSS projects (details in Chapter 5). The case study findings suggested that CI culture has a positive impact on the initiation of LSS projects, a finding for which literature support was subsequently found (Knapp, 2015; Schroeder et al., 2008; Sony et al., 2019). The case study findings suggested that CI culture is positively associated with LSS Project Initiation through the integration of values and behaviours when LSS projects are organised and done. More specifically, a CI culture was found to encourage organisational members to look for opportunities to improve processes, aligning perfectly with LSS principles (e.g., pursuing perfection in waste elimination in Lean and pursuing perfection in variation reduction and stability in SS).

3. *Contingency Variables affecting Project Performance is the Project's Residual Risks*

   The case study participants consistently emphasised the pivotal role of effective project initiation in mitigating risks and minimising the adverse effects of project-related contingencies, and that this is an essential element of LSS Project Initiation. For this reason, the researcher changed her initial moderator (Project Related Contingency Variables) to Project Residual Risks—a concept/construct that needs to be operationalised almost entirely using qualitative (case study) data.

Figure 6.1 presents the refined model and eight direct effect hypotheses (H1to H8), for which, literature support is presented in the next section.

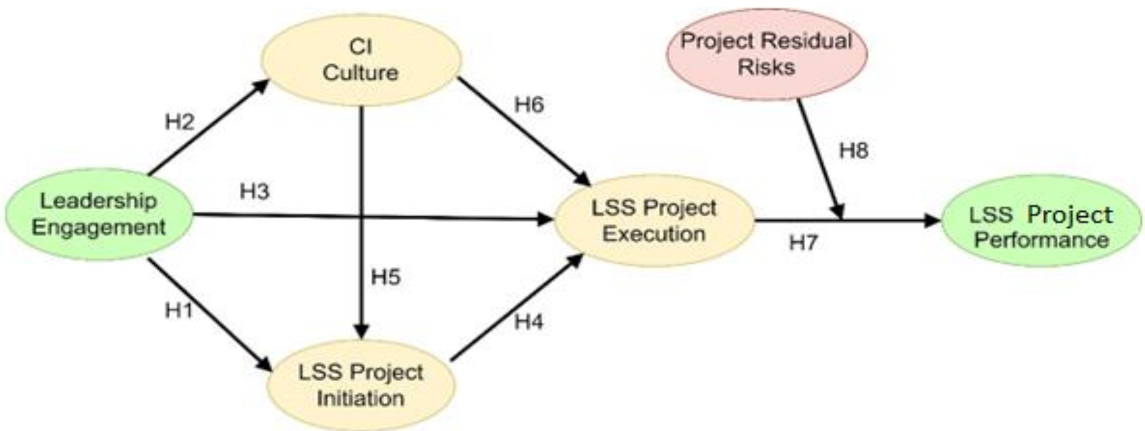



**Figure 6.1 Refined model and hypotheses**

As shown in Figure 6.1, the final model consists of six constructs: Leadership Engagement, CI Culture, LSS Project Initiation, LSS Project Execution, Project Residual Risks, and LSS Project Performance. Table 3.8 shows the working definitions of these constructs. Extant literature served as the primary source for the working definitions, operational definitions (the measures underpinning the construct), and hypothesised relationships between constructs. Case study data were used as a secondary source of information for verification purposes. It must be stated that case study data were extremely useful in rationalising construct operationalisations (operational definitions of the constructs) because each participant was asked to mention up to six ways the concept represented by a construct manifest in an LSS Project. For example, with regard Leadership Engagement, each informant was asked the following: "Suggest 4-6 ways Leadership Engagement manifests in an LSS project. *E.g., If the Leadership Engagement is low, you may be able to see that by their minimal involvement/enthusiasm in resource allocation decisions"* (see Part C of the questionnaire shown in Appendix B). The indicators of the constructs that were isolated for the development of a quantitative questionnaire (the survey instrument) were those that appeared in both the literature as well as the fieldwork.

## 6.3 Hypotheses Development via Extant Literature

A hypothesis is a proposed explanation based on limited information that can be tested to ascertain whether or not it is true; advancing hypotheses and testing them with real-word data is an essential feature in advancing scientific (Handfield & Melnyk, 1998; Karlsson, 2009). The researcher's theory consists of eight hypotheses presented in an orderly fashion—that is one relationship leading to another as shown in Figure 6.1. The key components of a hypothesis are the concepts involved in the idea and their relationship, which may be causal or purely correlational (Bryman, 2012). The concepts are represented as constructs in the hypothesis when the researcher defines how the concept manifests in the real world (i.e., observed through a set of directly observable variables). This definition is known as the operational definition of the construct (Bryman, 2012; Calder et al., 2021; Handfield & Melnyk, 1998). The reader's attention is now directed to the researcher's eight hypotheses stated in  Table 6.1.

**Table 6.1 Individual hypotheses and the supporting literature**

| Hypotheses and Accompanying Explanations | Supporting Literature |
|---|---|
| ***H1: Leadership Engagement has a direct positive effect on LLS Project Initiation.***<br>This hypothesis states that when leadership participates actively in (and supports) LSS initiatives (e.g., effective communication, empowering the LSS project team to achieve goals, sanctioning projects and providing resources) that positively impacts the initial stages of project development (of course the model posits that Leadership Engagement eventually results in LSS Project Performance through the causal mechanism presented in the researcher's theoretical model). | Firouznia et al., 2021; Vallejo et al., 2020 |
| ***H2: Leadership Engagement has a direct positive effect on CI Culture.***<br>This hypothesis states that Leadership Engagement in LSS projects fosters a CI culture in the organization. Creating a learning organisation, motivating, and inspiring the LSS project team to achieve goals are some of the things that the leadership does to foster a CI culture. | Assarlind et al., 2013; Bolden et al., 2011 |
| ***H3: Leadership Engagement has a direct positive effect on LSS Project Execution.***<br>This hypothesis suggests that greater the Leadership Engagement, the greater the project execution becomes, emphasising the importance of leadership not just in project initiation but throughout the project lifecycle. | Null et al., 2019; Sin et al., 2015 |
| ***H4: LSS Project Initiation has a direct positive effect on LSS Project Execution.***<br>This hypothesis suggests that the greater (more intense) the LSS project initiation, the greater the project execution becomes, indicating that a well-initiated project becomes a well-executed project. Part of the reason for this is strategic project selection and defining the scope of the project very clearly in the project initiation stage. | Laureani and Antony, 2019; Schroeder et al., 2008; Zu et al., 2008 |
| ***H5: CI Culture has a direct positive Effect on LSS Project Initiation***<br>This hypothesis suggests that stronger the CI culture, the stronger (more helpful) the LSS project initiation, emphasising the role of organisational culture in project initiation. This hypothesis explores how CI culture impacts LSS project initiation within an organisation. As mentioned earlier, case study findings were helpful in framing this hypothesis. | Barcia et al., 2022; Pande et al., 2000 |
| ***H6: CI Culture has a direct positive effect on LSS Project Execution***<br>The hypothesis suggests that the stronger the CI culture, the stronger (more helpful) the project execution. By fostering employee engagement, promoting a problem-solving mindset, encouraging adaptability, and facilitating effective communication and collaboration, a robust CI culture enhances LSS project execution. An organisation with a strong CI culture empowers its employees to participate actively. | Golini et al., 2016; Hellström et al., 2016 |
| ***H7: LSS Project Execution has a direct positive effect on LSS Project Performance***<br>This hypothesis suggests that the stronger the project execution, the stronger LSS performance becomes. The hypothesis is somewhat intuitive. A well implemented LSS project improves performance (e.g., becomes closer to the planned quality/operational target/s), reduces project cost, and increases customer satisfaction when the product/service is put in use. | Cua et al., 2001; Hoerl and Gardner, 2010 |

| Hypotheses and Accompanying Explanations | Supporting Literature |
|---|---|
| ***H8: Project Residual Risk moderates the LSS Project Execution → LSS Project Performance relationship.***<br><br>This hypothesis is meant to propose that the residual risk of a project acts as a moderator (retarder) in the results vs execution relationship. The moderation is such that when Project Residual risk is higher, LSS Performance is lowered for a given amount of LSS Project Execution than when Project Residual Risk is lower. The case study findings were helpful in framing this hypothesis.<br><br>Note that in model testing, H8 is represented as **H8a** (the main effect of Project Residual Risk on LSS Performance) and **H8b** (the Project Execution* Project Residual Risk two-way interaction on LSS Performance) to represent an interaction moderation. | Dao et al., 2016; Hallstrom et al., 2016 |

Finally, a hypothesis that is not related to the causal paths directly is posited to fill knowledge gap 2 (section 2.6.2) to answer RQ3 to achieve the fifth objective. In section 2.6.2 it was shown that although Lean and SS evolved in the manufacturing industry, and most Lean and SS practices and goals (e.g., process capability in terms of Cpk) become more straightforward in manufacturing, the principles, and practices of Lean and SS have now been translated to generic forms to make Lean and SS generalisable across both manufacturing and services (nonmanufacturing in general). Thus, the final hypothesis H9 is stated as follows:

***H9: The LSS model fits to nonmanufacturing as well as it would to manufacturing at a theoretical level.***

The phrase "LSS model" used in H9 refers to the LSS theoretical model developed by the researcher.

## 6.4 Construct Operationalisation

As mentioned earlier, both the extant literature and case research findings in response to questions in Part C of the interview questionnaire (Appendix D) were used to operationalize the constructs (i.e., to finalise the indicators belonging to the constructs). Figure 6.2 depicts the questions posed to determine the indicators associated with each construct. Nearly all the participants were able to either provide a list of indicators of the constructs or articulate their perception on what showed up (under each construct) based on previous successful LSS project implementations. Because many indicators/suggestions emerged due to the different ways participants respond to Part C of the interview questionnaire it was necessary to quantitatively reduce the number of indicators suggested to a manageable level to design measurement scales for the contract[21]. This process was greatly enhanced using “Meaning Cloud” a Microsoft Excel add-in (Dale, 2015). Meaning Cloud clusters and categorises similar terms and phrases within a qualitative dataset.

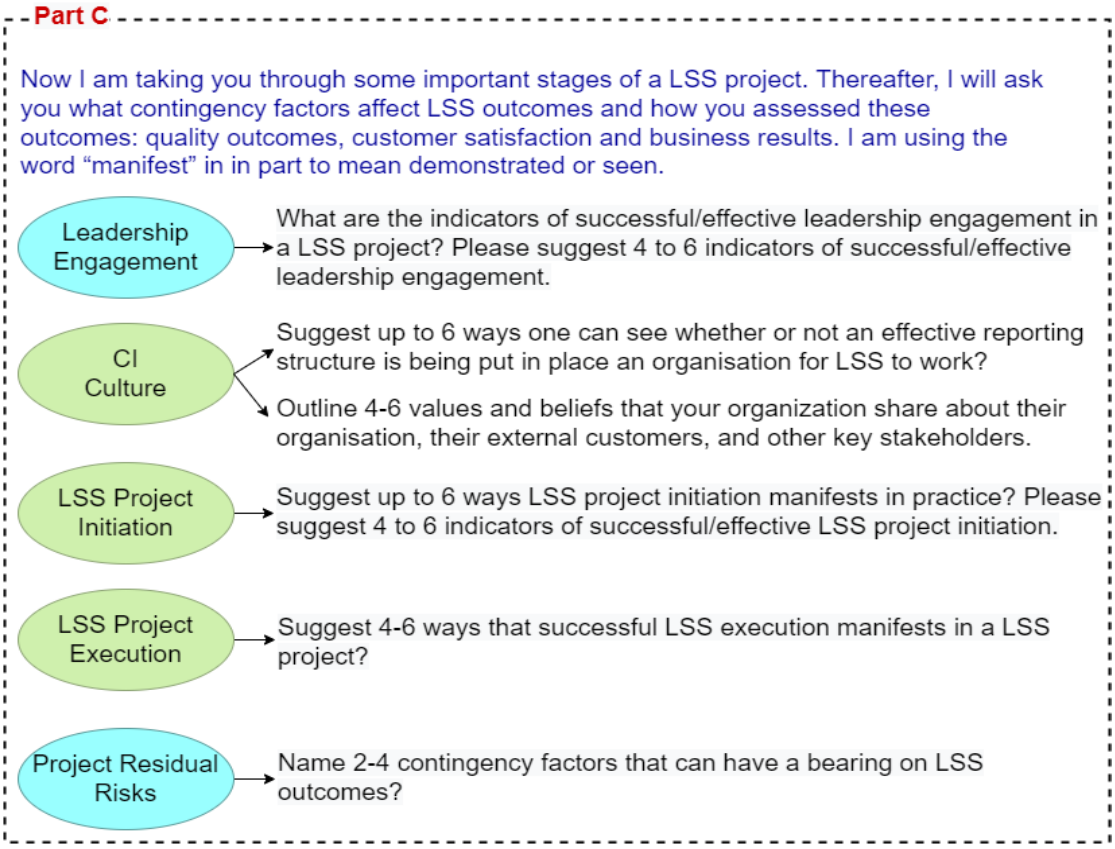



**Figure 6.2 Part C of the semi-structured interview questionnaire**

[21] The term “scale” does not apply to formative constructs due to conceptual reasons.

### 6.4.1 Leadership Engagement (LE)

**Working definition:** Leadership engagement is a concept that signifies leadership's active involvement in defining the problem, executing, reviewing, coaching, and mentoring the team to gain more commitment from them and engaging them effectively to ensure success (from Table 3.8 Working definitions of the concepts.

Leadership engagement is a vital component in the success of LSS projects (Abu Bakar et al., 2015; Adams-Robinson, 2021; Aij et al., 2015; Jacobs & Poddig, 2015). As leadership sets the tone for the entire project lifecycle, it can have a transformative effect in an organisation (Linderman et al., 2010; Sarin & McDermott, 2003). Engaged leaders actively promote LSS initiatives, providing constant support, guidance, and resources. Their involvement serves as a catalyst for change within the organisation, motivating teams, and stakeholders to fully commit to the project's objectives (Panat et al., 2014; Schroeder et al., 2005; Sony et al., 2020a). A well-engaged leader will also remove obstacles, giving teams the tools and autonomy, they need to implement LSS methodologies (Choo et al., 2015; Douglas et al., 2015; Jacobs, 2015). Along with the literature, case research findings (see Figure 6.3 for different manifestations of Leadership Engagement) provided evidence to support the notion that Leadership Engagement has a positive effect on the LSS Project Initiation, CI culture, and LSS Project Execution (H1, H2, and H3 respectively). As a result, Leadership Engagement acts as the driver of successful LSS Project Execution (Firouznia et al., 2021; Hilton & Sohal, 2012; Juliani & Oliveira, 2019; Schroeder et al., 2008), which is presented graphically in Figure 6.3. Figure 6.4 depicts different manifestations of the Leadership Engagement that the case study data synthesis captured, while Table 6.2 provides the operational descriptions of Leadership Engagement that were considered for inclusion in the survey instrument (Appendix – D) that was used for large sample quantitative data collection.

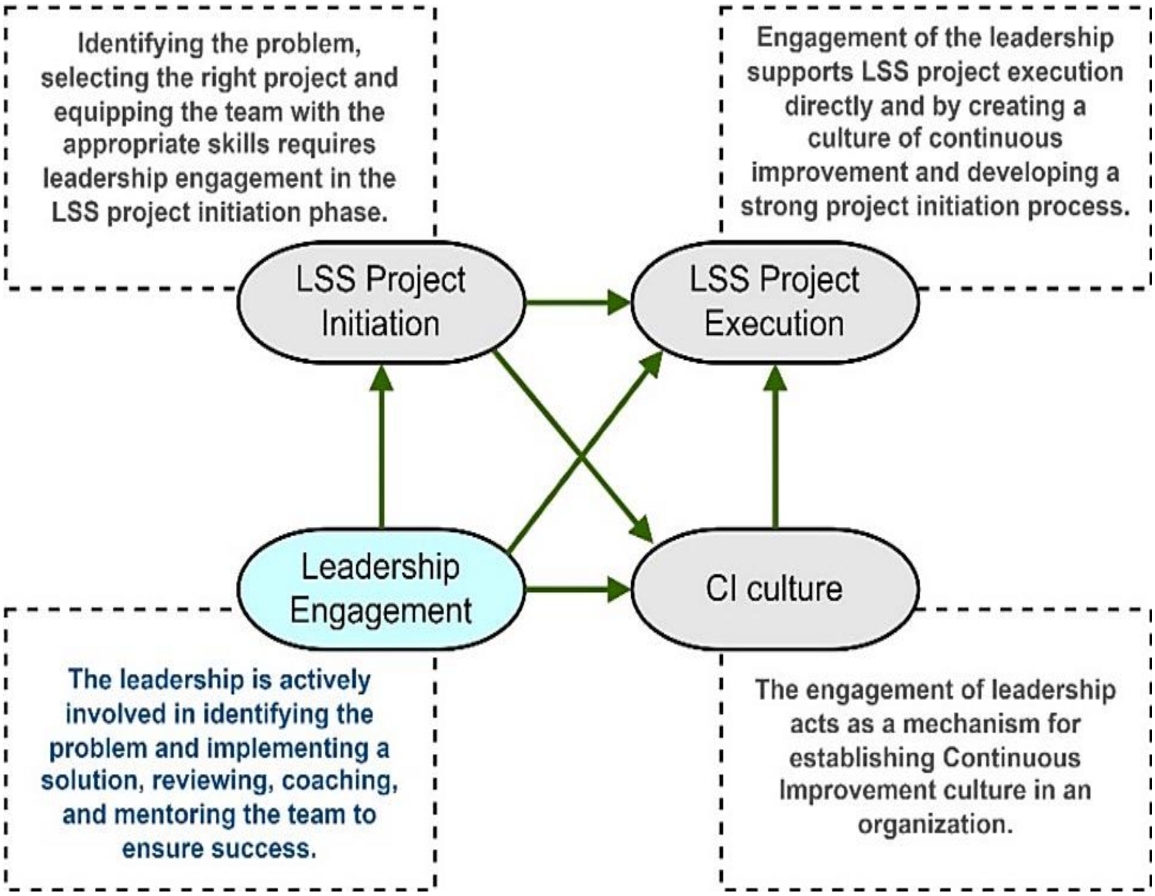



**Figure 6.3 Relationship between Leadership Engagement and other constructs**

**Table 6.2 Facets considered for operationalising Leadership Engagement**

| Label | Statement | Literature |
|---|---|---|
| LEN1 | Leadership was able to communicate effectively throughout the project with a solid communication plan. | (Abu Bakar et al., 2015; Jacobs & Poddig, 2015; Laureani & Antony, 2019; Netland, 2016; Yazdi & Esfeden, 2017; Zargun & Al-Ashaab, 2014) |
| LEN2 | Leadership created a learning environment. | (Aij et al., 2015; Alnadi & McLaughlin, 2021; Choo et al., 2015; Laureani & Antony, 2018) |
| LEN3 | Leadership empowered team members to accomplish goals and objectives throughout the project. | (Chiarini & Brunetti, 2019; Rathilall, 2014; Wilson et al., 2018) |
| LEN4 | Leadership actively participated in reviewing and evaluating the project performance. | (Ho et al., 2008; Rathilall, 2014; Sony et al., 2020a) |

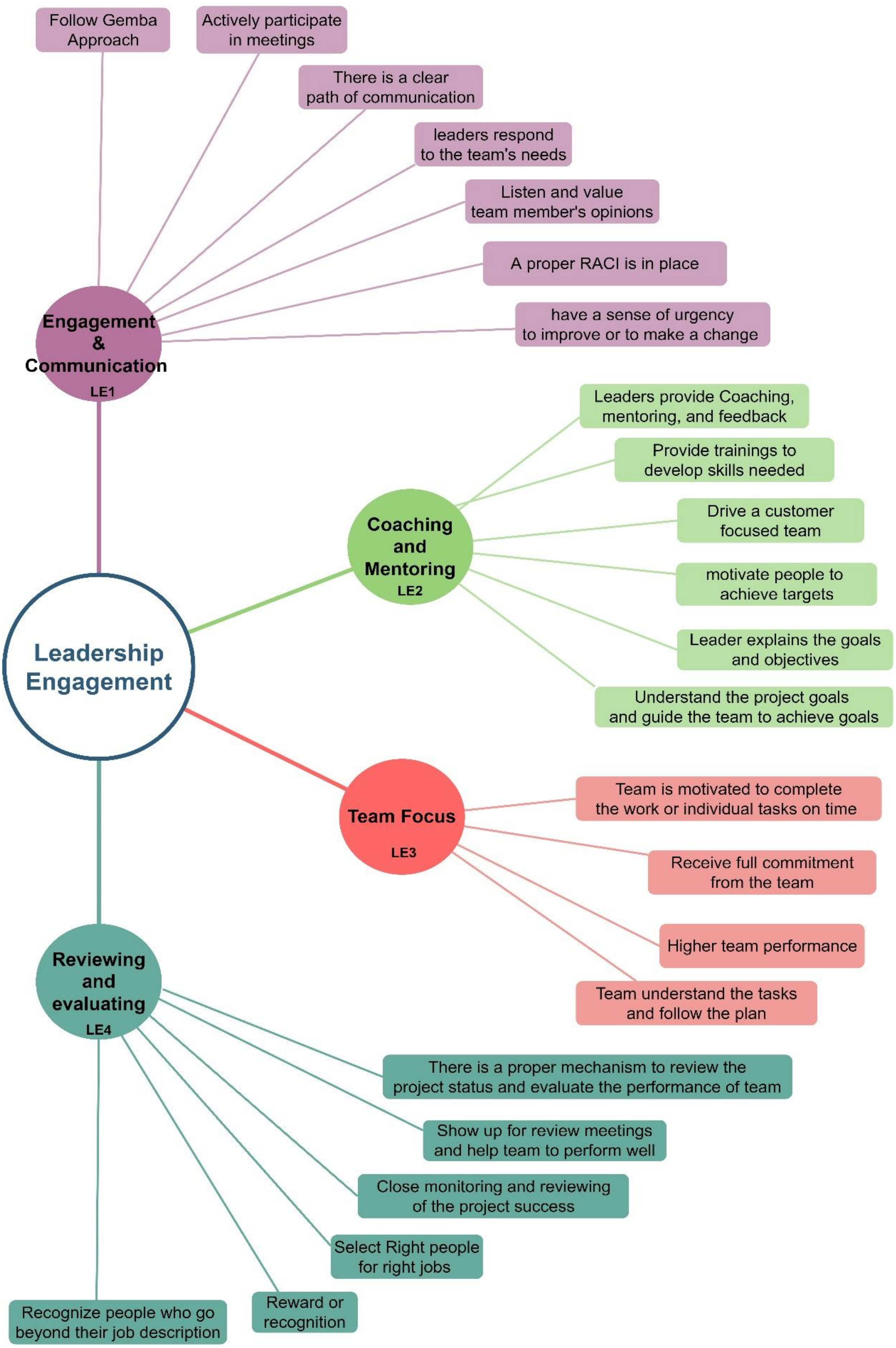



**Figure 6.4 Consolidated themes for Leadership Engagement from case research.**

### 6.4.2 Continuous Improvement Culture (CICUL)

**Working definition:** CI culture is a culture where people are empowered to make improvements on an ongoing basis, valuing everybody's contribution as well as training. A CI culture facilitates communication, identification of strategies, and challenges (from Table 3.8 Working definitions of the concepts.

An organisation's commitment to CI and quality and operational performance excellence is founded upon its CI culture; hence a CI Culture is an integral part of LSS project success (Kornfeld & Kara, 2011; Stelson et al., 2017). Employees at all levels are encouraged to identify inefficiencies, suggest improvements, and actively participate in problem-solving activities as part of the CI culture (Kowang et al., 2016). CI is characterised by a collective mindset. Researchers have demonstrated that a CI culture promotes employees' sense of ownership and responsibility, aligning them with the principles of LSS. Golini et al. (2016) and Hellström et al. (2016) demonstrate the direct positive impact of CI culture on LSS project execution, in line with the findings of this study. Based on case study responses, organisations that maintain a robust CI culture experience smoother project implementation because employees are more open to adopting LSS methodologies and are more receptive to change. Additionally, case study data suggested that a CI culture facilitates collaboration within and outside departmental boundaries, knowledge sharing, and adapting to new processes, all of which are integral components of a successful LSS project, enhancing the likelihood of success. Consequently, qualitative data confirmed that CI culture serves as the foundation of LSS implementation success; as one participant mentioned "the CI mindset is part of our company's DNA; we continually strive for improved operational efficiency, cost reduction, and most importantly, the satisfaction of our internal and external customers".

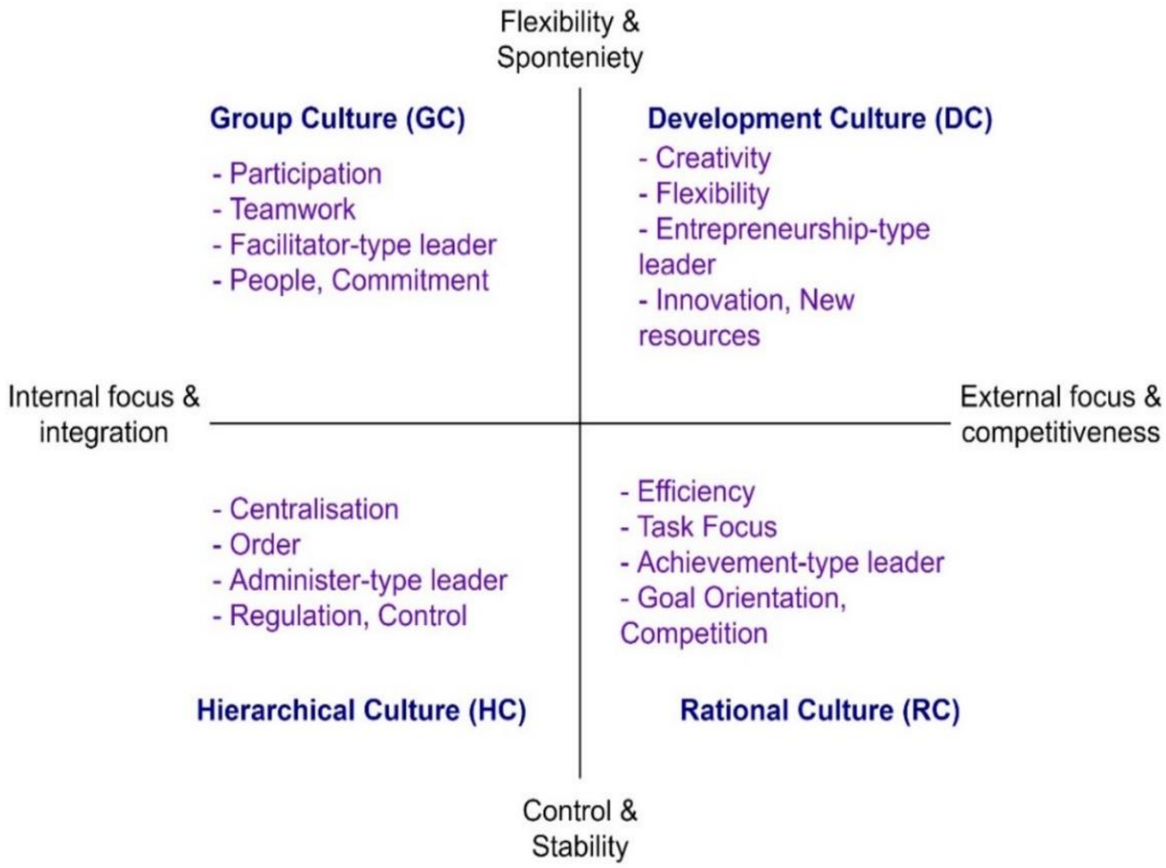



**Figure 6.5 Organisational culture and CI Culture (Adopted from Zu et al., 2010)**

Figure 6.5 shows the four organisational culture traits that Zu et al. (2010) used—Group Culture (GC), Development Culture (DC), Rational Culture (RC), and Hierarchical Culture (HC)—to test the relationship between the four culture traits (predictors) different elements of SS (response variables). They found that of the four culture traits, the Group, Development, and Rational cultures are the traits that are necessary for SS project success. Collaboration, employee involvement, and a familial atmosphere are all characteristics of the GC, all of which are consistent with continuous improvement principles. In an organisation with a CI culture, employees are encouraged to work together as a cohesive unit to achieve common goals. However, the traditional SS approach followed the CI structure, which shares several similarities with hierarchical systems in terms of structure (parallel-meso structure, belt system) and stability. A hierarchical culture is characterised by clear rules, procedures, and roles, all of which contribute to the systematic and structured approach inherent in CI.

Figure 6.6 depicts the different manifestations of the CI Culture that the case study data synthesis revealed, while Table 6.3 provides the operational descriptions of CI Culture that were considered for inclusion in the survey instrument that was used for large sample quantitative data collection.

**Table 6.3 Facets considered for operationalising CI Culture**

| **Label** | | **Statement** | **Literature** |
|---|---|---|---|
| CICUL1 | HC | The organisation promotes routinisation, formalisation, and structure. | (Iivari & Huisman, 2007; Timans et al., 2012a; Worley & Doolen, 2015; Zu et al., 2010) |
| CICUL2 | RC | The organisation places a strong emphasis on task focus, accomplishment, and goal achievement. | (Arumugam et al., 2016; Hilton et al., 2012; Koval et al., 2018; Linderman et al., 2003) |
| CICUL3 | GC | The organisation assesses employee concerns and ideas. | (Deranek et al., 2017; Laureani & Antony, 2017; Pearce et al., 2018) |
| CICUL4 | GC | The organisation empowers employees to act. | (Deranek et al., 2017; Iyede et al., 2018; Pearce et al., 2018) |
| CICUL5 | DC | The organisation employs creative problem-solving methods. | (Alsyouf et al., 2018; Deshmukh & Mukti, 2018; Hilton et al., 2012; Kane, 2020; Shokri & Nabhani, 2015) |
| CICUL6 | DC | The organisation is committed to developing its personnel and expanding its knowledge to achieve its goals. | (Cherrafi et al., 2017; Gitlow, 2008; Shokri & Nabhani, 2015; Sunder M, 2016) |
| CICUL7 | GC | Human relations, teamwork, and cohesion are important to the organisation. | (Abid et al., 2020; Abu Bakar et al., 2015; Hill et al., 2017; Nair et al., 2011) |
| CICUL8 | GC | The organisation encourages Participation, and open discussion. | (Stelson et al., 2017a; Sunder M, 2016; Sutton, 2015; Vallejo et al., 2020) |
| CICUL9 | RC | Performance measures of the organisation include efficiency, productivity, and profitability. | (Arumugam et al., 2016; Hilton et al., 2012; Koval et al., 2018; Linderman et al., 2003) |
| CICUL10 | DC | The organisation focuses on innovation and change. | (Hoerl & Gardner, 2010; Taner, 2012; Uluskan, 2016; Yadav & Desai, 2017; Zu et al., 2008b) |
| CICUL11 | DC | Decentralisation and flexibility are key components of the organisation. | (Jacobs & Poddig, 2015; Kendrick et al., 2017; Pakdil & Leonard, 2015) |
| CICUL12 | RC | Organisational objectives, goals, and directions are clearly defined. | (Knapp, 2015; Papic et al., 2017; Price et al., 2018; Stelson et al., 2017a) |
| CICUL13 | HC | The organisation is focused on ensuring continuity, stability, and order. | (Dagnino & Cinici, 2016; Farris et al., 2009; Stelson et al., 2017a) |
| CICUL14 | HC | The Organisations focus on predictable performance outcomes. | (Iyede et al., 2018; Linderman et al., 2003; Näslund, 2008; Pakdil & Leonard, 2016) |

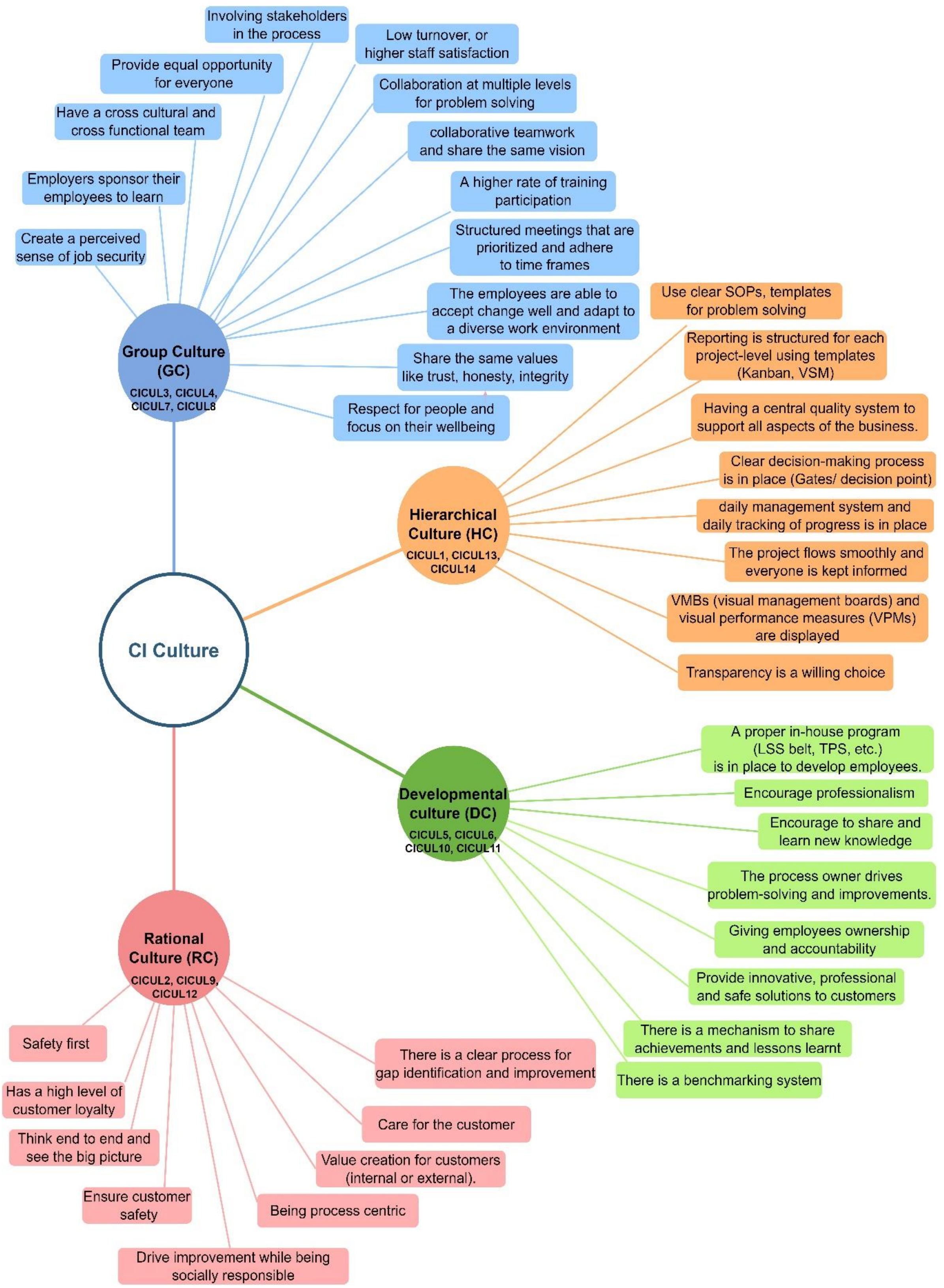



**Figure 6.6 Consolidated themes for CI Culture from Case research**

### 6.4.3 LSS Project Initiation (PRIN)

**Working definition:** LSS project initiation is the process of identifying a problem or opportunity by listening to the four influential voices (customer, process, stakeholders, and business) and performing a functional analysis (feasibility/risk analysis etc.) to develop a tactical plan to implement the project (from Table 3.8 Working definitions of the concepts.

Project initiation is one of the key elements in the success of an LSS project, as it includes several critical components, including an effective initial analysis, which sets the project up for success (Carleysmith et al., 2009; Crowther & Lancaster, 2008; Ruben et al., 2018a; Söderberg, 2020). As part of this process, customers' voices are actively listened to, existing processes are understood, stakeholder perspectives are considered, and comprehensive business analyses are conducted (Cheng & Chang, 2012; Rodgers & Antony, 2019). In addition to establishing the foundation for a successful project, this initial analysis will ensure that the chosen project is aligned with the company's strategic objectives and goals (Lameijer et al., 2019; Sony et al., 2020b). Case study data synthesis indicated that correct project selection and prioritisation ensures that resources are allocated to projects that provide the greatest value and that project selection should be data driven and efficiency, quality, and customer satisfaction are the criteria frequently used in selecting LSS projects. The case study responses also suggested that the project scope needs to be clearly defined to define what must be included in the project and, equally importantly, what must not be included. The case study participants also alluded to goal requirements that fall in line with specific, measurable, achievable, relevant, and time-bound (SMART) goals; this is to guide the team throughout the project lifecycle.

**Table 6.4 Facets considered for operationalising LSS Project Initiation**

| Label | Statement | Literature |
|---|---|---|
| PRIN1 | The initial stage of the project involved identifying the gap and its impact on the business. | (Oliver et al., 2019; Sodhi et al., 2019; Zhang et al., 2008) |
| PRIN2 | The team utilised a well-defined project selection strategy. | (Mundra & Mishra, 2021; Rathilall, 2014; Silva et al., 2018) |
| PRIN3 | The project had a well-defined scope | (Albliwi et al., 2014; Antony et al., 2017a; Söderberg, 2020) |
| PRIN4 | The improvement resulting from the intervention had a well-defined scientific basis. | (Stankalla et al., 2018; Zu et al., 2008a; Zugelder, 2012) |
| PRIN5 | LSS project objectives were aligned with business objectives during the initiation phase (Safety, Quality, Costs, Delivery, etc.). | (Sony et al., 2019; Sunder M et al., 2018; Vallejo et al., 2020) |
| PRIN6 | LSS project initiation included developing a clear execution plan, roles, responsibilities, and methods of communication. | (Swink & Jacobs, 2012; Timans et al., 2012b) |

Table 6.4 provides the operational descriptions of LSS Project Initiation that were considered for inclusion in the survey instrument that was used for large sample quantitative data collection while Figure 6.7 depicts the different manifestations of LSS Project Initiation that the case study data synthesis revealed.


**Figure 6.7 Consolidated themes for LSS Project Initiation from case research**

### 6.4.4 LSS Project Execution (PREX)

**Working definition:** LSS project execution involves managing people, processes, and information distribution to ensure successful project deliverables, dissecting tasks into time-bound activities, identifying constraints, and providing resources and training (from Table 3.8 Working definitions of the concepts).

Regular and transparent communication both with the project team and stakeholders is vital for ensuring project success (Nonthaleerak & Hendry, 2008; Null et al., 2019; Zhang et al., 2008). This is because regular and transparent communication helps to guarantee that the project requirements are met, progress is accurately reported, and potential gaps are promptly addressed (Marion et al., 2016; Ramasamy & Yusof, 2015). Having such communication fosters a collaborative environment, which plays a significant role in project success. LSS project execution requires tracking project progress and proactively identifying risks and uncertainties. To monitor progress and performance, key performance indicators (KPIs) are essential. Using these metrics, the team can make data-driven decisions and address deviations from the project plan promptly (Marion et al., 2016; Snee & Hoerl, 2007). The case study participants opined that a resolute and well-resourced team is crucial to the achievement of LSS project objectives, while innovative approaches facilitate change and enhance quality assurance. Finally, the participants also referred to allocation of necessary resources to enable the team to perform effectively.

**Table 6.5 Facets considered for operationalising LSS Project Execution**

| Label | Statement | Literature |
|---|---|---|
| **PREX1** | There was regular communication with the team and stakeholders regarding project needs and reporting status. | (Albliwi et al., 2015; Carrier, 1987; Gijo et al., 2014) |
| **PREX2** | A robust risk management strategy was implemented to reduce risks and uncertainties during the execution phase. | (Carrier, 1987; Golini et al., 2016; Hellström et al., 2016; Tatikonda & Rosenthal, 2000) |
| **PREX3** | LSS project execution began with a review of customer requirements, CTQs and a mapping of the project deliverables. | (Stankalla et al., 2018) |
| **PREX4** | Project performance was measured using key performance indicators (KPIs) during the execution. | (Antony et al., 2017b; Bajjou & Chafi, 2019; Marion et al., 2016) |
| **PREX5** | Dedicated time and resources were available to build a cohesive team. | (Ben Ruben et al., 2017; Bhat et al., 2019; Lertwattanapongchai & William Swierczek, 2014) |
| **PREX6** | Utilised innovative technology to tackle technical challenges during execution. | (Mundra & Mishra, 2021; Nair et al., 2011; Sodhi et al., 2019) |
| **PREX7** | Implemented tools and processes to facilitate change | (Abu Bakar et al., 2015; Douglas et al., 2015; Stankalla et al., 2018) |

| Label | Statement | Literature |
|---|---|---|
| **PREX8** | Tools and processes were implemented to ensure the quality of deliverables. | (Stankalla et al., 2018; Swink & Jacobs, 2012; Vallejo et al., 2020; Zu et al., 2008a) |

Table 6.5 provides the operational descriptions of LSS Project Execution that were considered for inclusion in the survey instrument that was used for large sample quantitative data collection while Figure 6.8 depicts the different manifestations of LSS Project Execution that the case study data synthesis revealed.

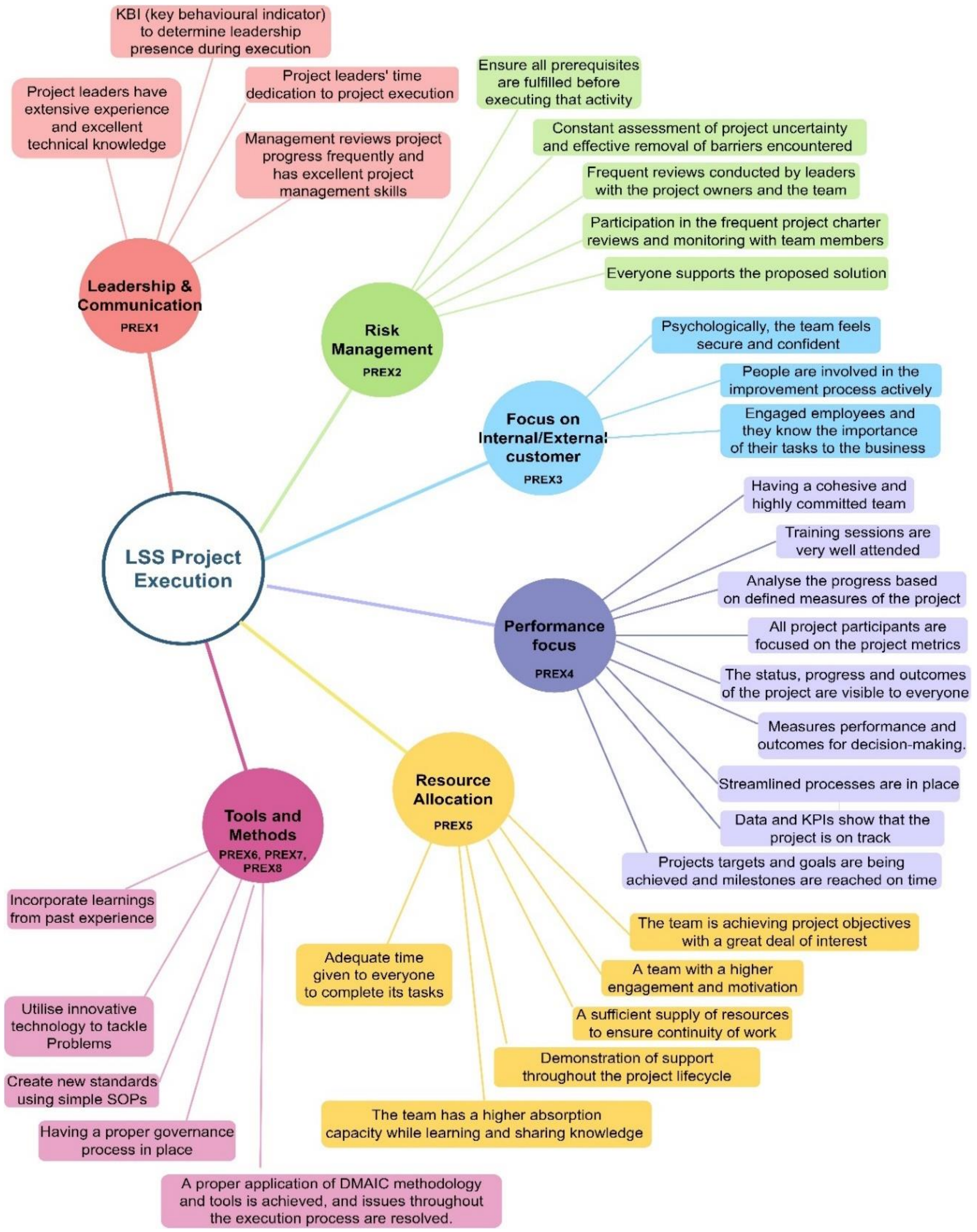



**Figure 6.8 Consolidated themes for LSS Project Execution from case research**

### 6.4.5 LSS Project Performance (LSSPER)

**Working definition:** LSS performance means outcomes of an LSS project that contribute towards effectiveness and competitiveness of the firm. LSS results in reduced defects, waste, and enhanced process reliability, efficiency, effectiveness, and profitability after project completion, with established controls for sustained improvement.

Improving operational efficiency and reducing defects and rework increases customer satisfaction (Sin et al., 2015; Zu et al., 2008b). Achieving quality improvement targets is crucial for LSS projects, as it indicates their effectiveness in promoting positive change. Another key marker of LSS project success is meeting customer expectations and needs, which is reflected in the reduction of customer complaints and increased customer loyalty (Schroeder et al., 2005; Sutherland et al., 2020; Wilson et al., 2018). Some case study participants opined that commitment to sustainability is essential, reflecting the project's social responsibility and environmental awareness. The researcher observes that Green LSS is an emerging concept (e.g., Farrukh et al., 2022; Kaswan & Rathi, 2020) but it was decided that environmental sustainability should not be considered as a generalisable goal of an LSS project. However, social responsibility was considered as an attribute of LSS project outcomes because waste or deviations from targets/variation is a loss to society (Sony et al., 2020b; Surange, 2015; Taguchi & Phadke, 1989). The researcher also considered stakeholder satisfaction (another idea opined by the participants) as an indicator of LSS Project Performance. Figure 6.9 depicts the different manifestations of LSS Project Performance that the case study data synthesis revealed (six key areas were identified), while Table 6.6 provides the operational descriptions of LSS Project Performance that were considered for inclusion in the survey instrument that was used for large sample quantitative data collection.

**Table 6.6 Facets considered for operationalising Project Performance**

| Label | Statement | Literature |
|---|---|---|
| LSSPER1 | The LSS project resulted in a reduction in defects and rework. | (E. V. Gijo et al., 2018; Endara et al., 2019; Sin et al., 2015b; Zu et al., 2008b) |
| LSSPER2 | The LSS project resulted in improved delivery of products or services. | (Stankalla et al., 2018; Zu et al., 2008b) |
| LSSPER3 | The number of customer complaints decreased after the implementation of the LSS project. | (Chiarini & Brunetti, 2019; Zu et al., 2008b) |
| LSSPER4 | The LSS project reduced our organisation’s waste while being socially responsible. | (Alsmadi et al., 2012; Antony et al., 2008; van den Bos et al., 2014) |

| Label | Statement | Literature |
|---|---|---|
| LSSPER5 | The LSS project resulted in improved cost savings. | (Sarhan et al., 2019; Selvaraju et al., 2019; Shah & Ward, 2003) |
| LSSPER6 | The LSS project achieved its expected quality improvement targets. | (Stelson et al., 2017b; Zu et al., 2008b) |
| LSSPER7 | The LSS Project related stakeholders were satisfied with the project results. | (Campos, 2013; Dabholkar, 2015; de Koeijer et al., 2014; Zu et al., 2008b) |


**Figure 6.9 Consolidated themes for LSS Project Performance from case research**

### 6.4.6 Residual Risks (PRRISK)

**Working definition:** Project residual risk refers to the risk that remains after mitigating major risks. The project residual risk increases with project complexity and uncertainty (from Table 3.8 Working definitions of the concepts).

Effective risk management plays a pivotal role in LSS projects—in fact, CI in general (Andersson et al., 2020; Cagnin et al., 2021; Maleyeff et al., 2012). Residual risks was a term that emerged during the case research stage as a concept that replaces traditional project risk factors—project complexity and project uncertainty—that moderate the relationship between project execution and project performance (Floricel et al., 2016; Heredia-Rojas et al., 2022; Padalkar et al., 2016). It was found that despite best efforts to identify risks during the planning stage, several reasons including the inability to anticipate technology needs, difficulties in assessing interdependent project tasks, challenges in obtaining approvals (in hierarchical organisations), and unpredictability in the external environment affecting business, social, and environmental goals, remain as residual risk (see Table 6.7 for supporting literature). The residual risk is something that will also be present in a project (much the same way as variation in a process) and it is important to minimise it. Failure modes and effects analysis (FMEA) is a well-known risk assessment tool that can be considered to reduce residual risk (Kollárová *et al.*, 2021; Lo *et al.*, 2018; Wu *et al.*, 2021). Figure 6.10 depicts the different manifestations of Project Residual Risks that the case study data synthesis revealed (six key areas were identified), while Table 6.7 provides the operational descriptions of Project Residual Risks that were considered for inclusion in the survey instrument that was used for large sample quantitative data collection.

**Table 6.7 Facets considered for operationalising Project Residual Risks**

| Label | Statement | Literature |
|---|---|---|
| PRRISK1 | The project team were unable to anticipate technology needs. | (Tatikonda & Rosenthal, 2000; Thomé & Sousa, 2016; Zhang et al., 2016; Zhang et al., 2020) |
| PRRISK2 | Due to the interdependence of project tasks, it was difficult for the team to assess the project needs. | (Hsieh et al., 2012; Ishtiaq & Jahanzaib, 2017) |
| PRRISK3 | It was difficult for the project team to obtain approvals due to the organisation's hierarchical structure. | (Hsieh et al., 2012; Ishtiaq & Jahanzaib, 2017; Maylor & Turner, 2017; Zhang et al., 2020) |
| PRRISK4 | The project team found it difficult to assess the expectations of external stakeholders due to regulatory changes. | (Maylor & Turner, 2017; Thomé & Sousa, 2016; Zhang et al., 2020) |

| Label | Statement | Literature |
|---|---|---|
| PRRISK5 | Due to uncertainties in the external environment, the team was unable to predict business, social and environmental impacts (e.g., politics, economics, the law, and natural conditions). | (Ishtiaq & Jahanzaib, 2017; Maylor & Turner, 2017) |

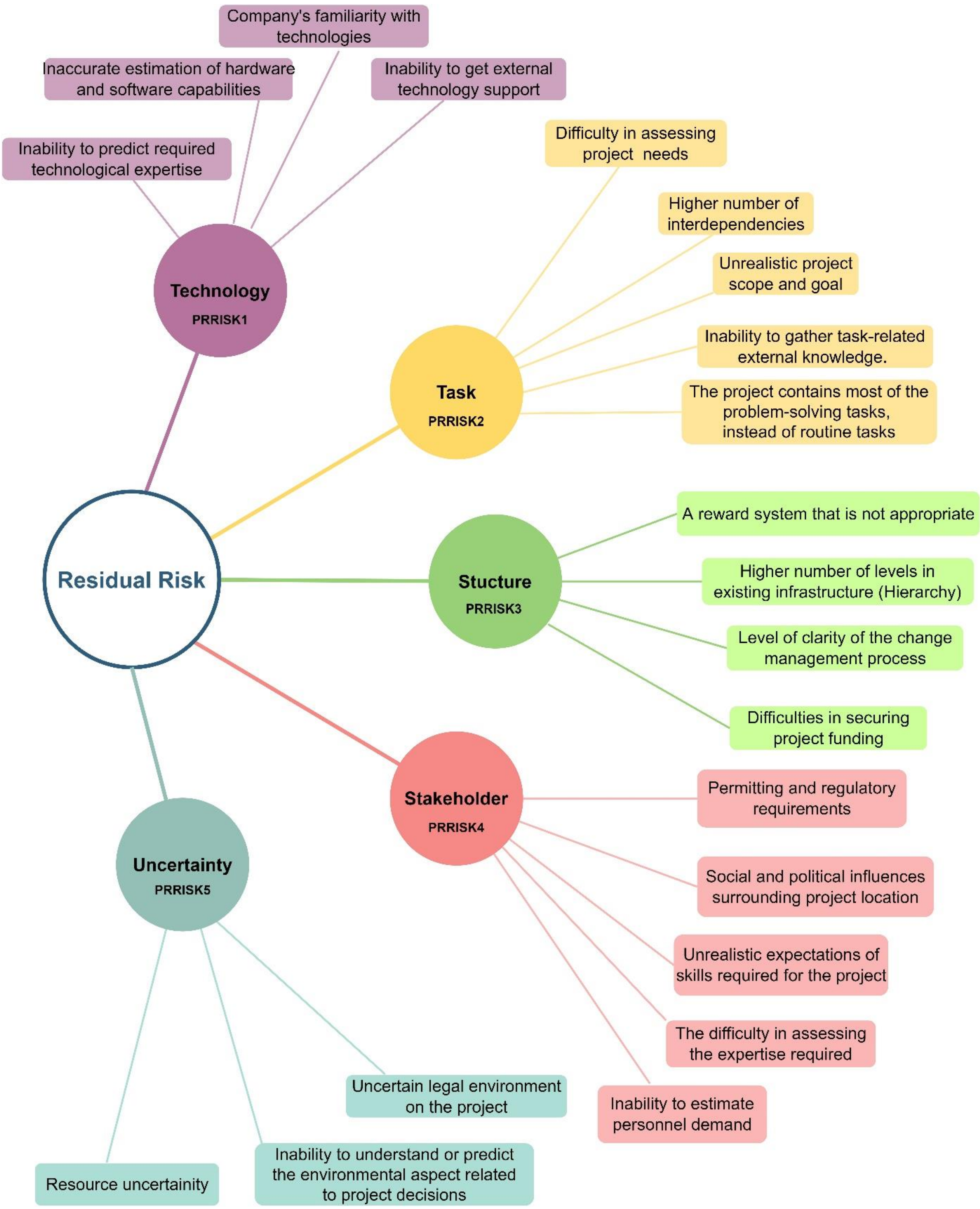



**Figure 6.10 Consolidated themes for Residual Risks from case research**

The survey instrument used for collecting data on the indicators of the constructs is shown in Appendix D (survey data collection was described in Chapter 4). Appendix D also includes demographics questions (see Part 1) that were deemed necessary for the study.

## 6.5 Chapter Summary

The main purpose of this chapter was to identify the measures of the constructs, based on the literature as well as field data (case study data). The indicators chosen for the survey instrument (Appendix D) are the ones that were jointly supported by the literature and case study data. The measures have been presented in the survey instrument as statements for which agreement of the respondents was sought in a 1-7 Likert scale, as stated in Chapter 4. Some constructs possess many indicators. CI Culture stands out with 13 indicators, as shown in Table 6.3. The quantitative data analysis shown in the next chapter shows that despite so many measures being used to capture different facets of the CI culture, this construct remains a unidimensional construct. In survey questionnaires, reverse coding disrupts response patterns, ensures thoughtful responses, and balances scales with both positively and negatively worded items to minimize response bias, improve validity, and enhance reliability. Rather than responding to each item in a uniform pattern or by social desire, it is essential to obtain accurate and meaningful data. Based on Table 6.7, the researcher reverse-coded the indicators for residual risks related to projects.

# CHAPTER 7
# QUANTITATIVE DATA ANALYSIS AND HYPOTHSIS TEST RESULTS

## 7.1 Introduction

The qualitative study results and the accompanying discussion was provided in Chapter Five. These findings were helpful in at least two ways. Firstly, the qualitative study enabled the researcher to reinforce (or reconfirm) the determinants of LSS and the theoretical relationships between these determinants initially identified through literature synthesis. Secondly, the qualitative study enabled the researcher to operationalise the constructs more reliably to suit the industry (LSS) context, which would otherwise have been difficult to accomplish via literature review alone. The outcome of the qualitative study is thus positing a testable theoretical model that predicts and explain how LSS leads to performance, at project level (this pertains to answering RQ1). In addition, chapter five identified project-related residual risks associated with LSS project implementation (this pertains to answering RQ2).

In this chapter, the researcher presents quantitative data analysis results that originated from the questionnaire development, pretesting, and evaluation presented in Chapter 4 (section 4.5.3). While presenting hypothesis test results is the main aim of this chapter, this chapter covers other prerequisites such as presenting descriptive statistics of the respondents, descriptive statistics of the 45 indicators used to operationalise the constructs, and evidence of reliability validity of the theoretical constructs to legitimise hypothesis test results. Overall, the results shown in this chapter provide empirical support for the results discussed in Chapter 5, thus resulting in more robust answers to RQ1, RQ2 and RQ3.

This chapter is organised as follows. Section 7.2 presents the distribution of responses across different regions along with a justification of the response rate, sample composition and sample size. Section 7.3 presents the demographic profiles of the respondents, including LSS expertise, experience, sector, the problem-solving approach, tools being used, and duration of the respondents' LSS projects. Information in section 7.2 and 7.3 was also used to justify suitability of the data for hypothesis testing. Section 7.4 presents data screening, covering how missing values were dealt with, examination of the descriptive statistics of the 45 indicators belonging to the six theoretical constructs and testing for absence of method bias in the indicator data.

Section 7.5 covers the examination of the measurement model to ensure reliability and validity of the constructs; this is a prerequisite for testing the hypothesised relationships between the constructs. Section 7.6 covers the evaluation of hypothesised theoretical relationships between the constructs, based on estimated structural model parameters and their significance level (p-values). Section 7.7 covers the overall goodness of fit of the structural model in a causal predictive sense. This is a gauge of how strong the hypothesised relationships are. Section 7.8 presents the correlations between the constructs and their implications. Section 7.9 tests the hypothesised relationships between the constructs between the nonmanufacturing group and the manufacturing group to test the hypothesis *"The LSS model fits to nonmanufacturing as well as it would to manufacturing at a theoretical level"* (H9). Test results of H9 enables the researcher to answer RQ3. Section 7.10 discusses the hypothesis test results. Finally, section 7.11 summarises and concludes this chapter (see Figure 7.1).

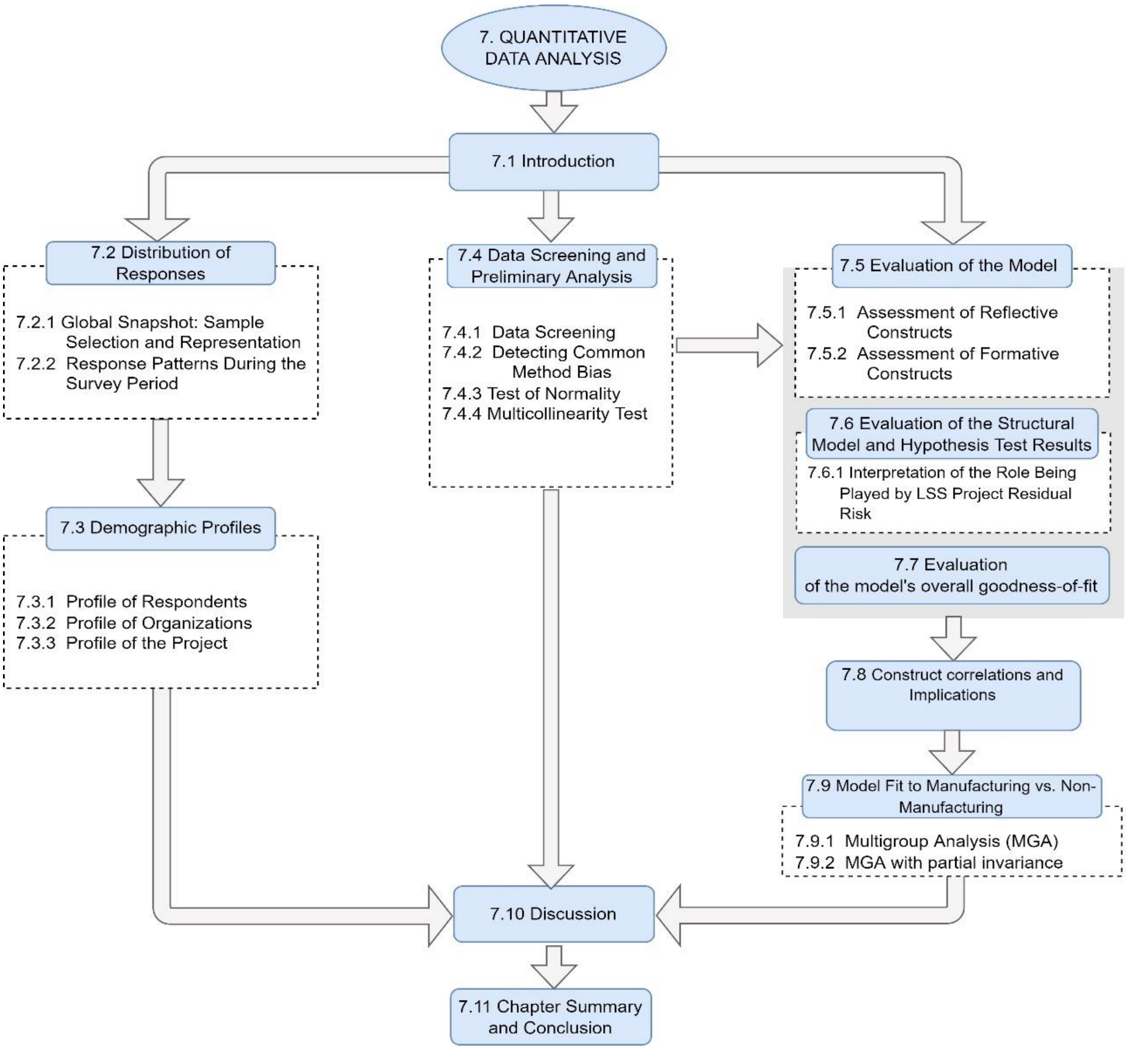



**Figure 7.1 Structure of the chapter**

## 7.2 Distribution of responses

### 7.2.1 Global snapshot of survey responses

To ensure worldwide representation, the survey was sent to 1259 LSS experts around the world who represent countries of diverse national cultural clusters (Dankert et al., 2017; Jacobs, 2015). From this distribution of surveys there were 345 responses received, representing a response rate of approximately 27%. Among those 345 responses, only 296 were deemed useful by the level of completion. This results in a valid (net) response rate of 23.51%, which is an acceptable response rate for an online survey (Shannon & Bradshaw, 2002; Van Mol, 2017). Equally importantly, the net sample size of 296 exceeded the minimum sample size (*n* = 275) estimated based on power analysis based on the inverse square root method (Kock & Hadaya, 2018) assuming a 0.15 path coefficient, 5% significance level, and 80% power[22]. A breakdown of the response rate is shown in Table 7.1.

**Table 7.1 Statistics of survey completion time**

| | Frequency | Rate % |
|---|---|---|
| Questionnaires administered | 1259 | 100.00% |
| Responses received | 345 | 27.40% |
| 90% completion | 296 | 23.51% |
| Excluded from analysis | 49 | 3.89% |
| Valid responses | 296 | 23.51% |

Figure 7.2 depicts a representation of responses by national culture clusters[23]. As shown in Figure 7.2 among the invited experts, 30% were from Anglo countries, 27% from Southern Asia, 7% from Eastern Europe, and approximately 6% each from Latin Europe, the Middle East, Confucian Asia, and Germanic Europe. Additionally, approximately 5% of the experts were from Latin America, while 3% were from Nordic European and Sub-Saharan African countries. A diverse range of cultural perspectives captured in this study implies that while the sample is not a probability sample, it is representative enough to make the statistical inferences

[22] 80% power is typical in statistical analysis. A power is 80% means setting the beta risk at 20% (Power = 1 – beta risk), which is justified because beta risk is typically set at four times the alpha risk (significance level) (Cohen, 1992).

[23] The researcher used the 2020 GLOBE study classification to assign a country to a particular cluster. The details are found in the following URL: https://globeproject.com/results/clusters/anglo?menu=list#list

meaningful. Figure 7.3 depicts the countries to which the respondents belong, providing further evidence of the global nature of the study.

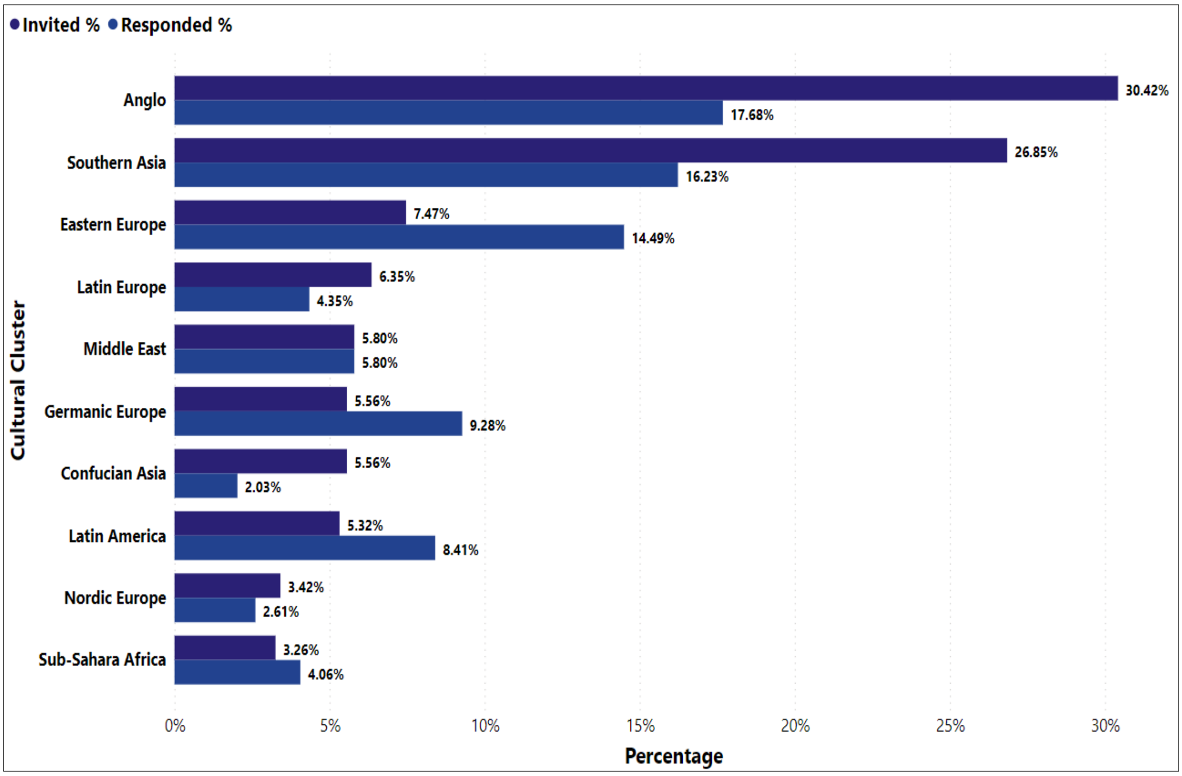



**Figure 7.2 Percentage of Invited LSS experts from diverse cultural clusters**


**Figure 7.3 Respondents from around the world, reflecting a global sample**

## 7.3 Demographic Profiles

### 7.3.1 Profile of Survey Respondents by their Expertise and Experience

The purpose of profiling the respondents by expertise (Figure 7.4) is to demonstrate that the respondents possess the requisite domain knowledge (e.g., LSS knowledge, quality improvement contextual knowledge such as CI culture, LSS project results and so forth) to respond to the survey. This is to reduce the risk of bias (including CMB) and to increase the credibility of the findings. Figure 7.4 shows that more than 80% of the respondents have LSS black belts and master black belts and the remainder also would have possessed the requisite domain knowledge to respond to the survey.

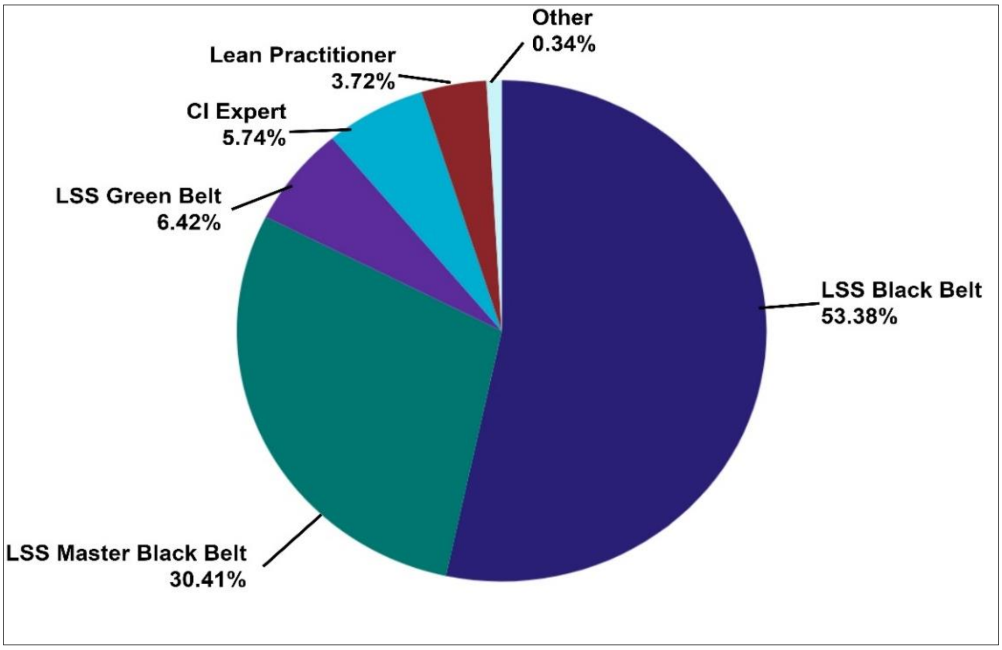



**Figure 7.4 Classification of respondents by their expertise**

The purpose of examining the years of experience of the respondents (Figure 7.5), is similar to that of profiling the respondents by their expertise. The mean experience of 11 yrs. (median = 10 yrs.) suggests that the respondents are experienced, while the relatively high standard deviation (6yrs approx.) suggests that there is high variability of experience (the interquartile range = 9 yrs.) which is something that the researcher expected. It must be noted that domain expertise is not solely dependent on the length of practice. Continuous learning, exposure to diverse projects, and ongoing skill development also play significant roles in determining expertise.

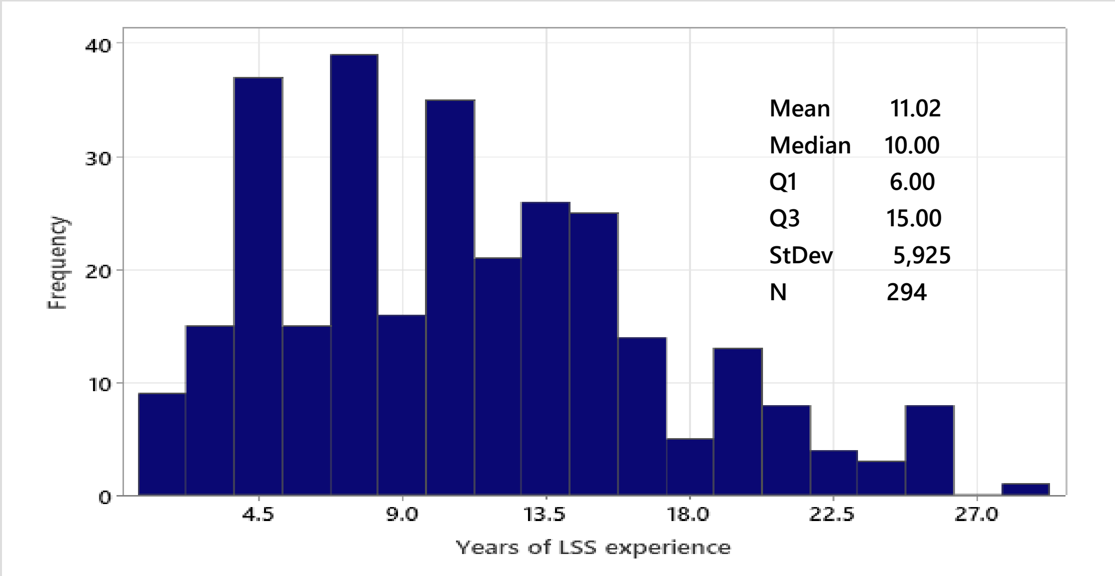



**Figure 7.5 The distribution of respondents by experience**

Figure 7.6 shows the relationship between the three-level factor "Level of LSS experience" (in terms of LSS certification) and years of experience. Of the 267 (90.2% of total usable respondents) certified respondents 19 (7.1%) happened to be LSS Green Belts, 158 (59.2%) happened to be LSS Black Belts, while 90 (33.7%) happened to be LSS Master Black Belts. Figure 7.6 shows that Level of LSS experience (in terms of LSS certification) and years of experience are related. Of the variability of data on Years of LSS experience, 22.63% of the variability is explained by the factor Level of Experience in LSS, in terms of LSS certification.

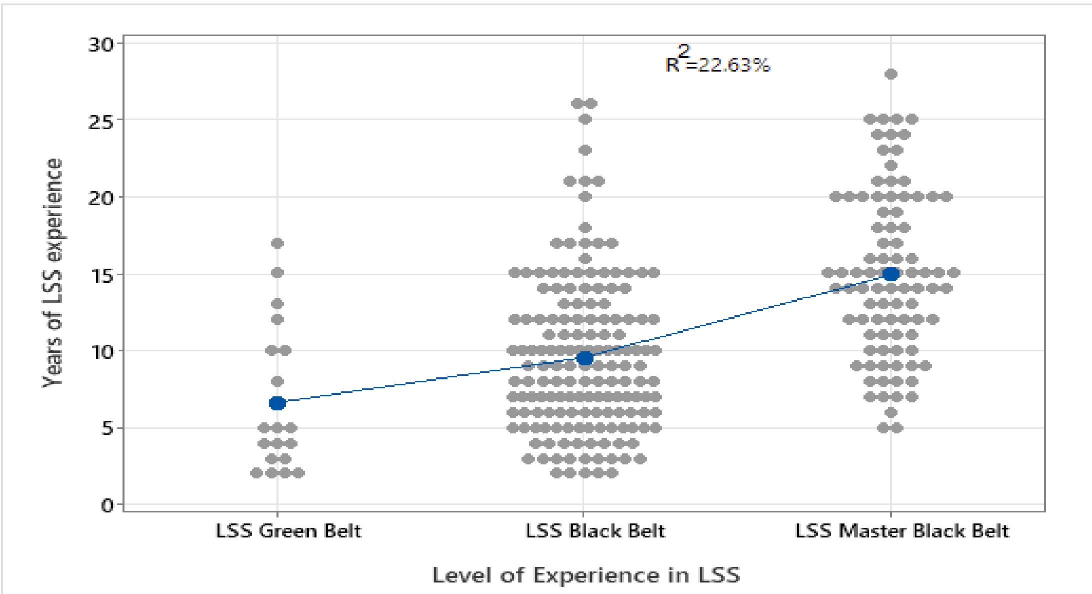



**Figure 7.6 Individual value plot of years of LSS experience vs level of experience in LSS**

### 7.3.2 Problem Solving Approach

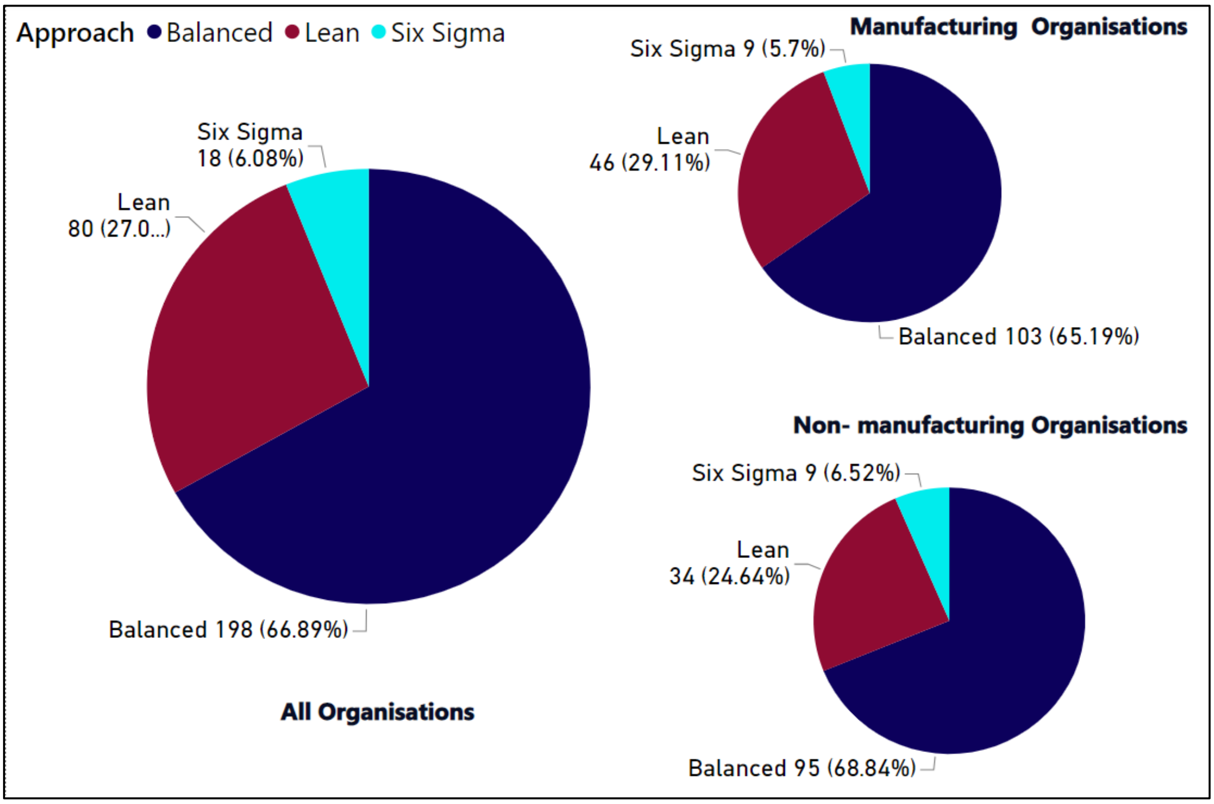



**Figure 7.7 The problem-solving approach used for the LSS project relevant to the study**

Figure 7.7 depicts how the respondents classified their problem-solving approach, given the three choices: predominantly Lean (labelled Lean), predominantly SS (labelled SS), and an approximately equal mix of Lean and SS (labelled Balanced). The two smaller pi-charts show the classification by sector. Figure 7.7 shows that 2/3 of respondents ($n$ = 198 out of the 296 respondents) perceived that their project used both Lean and SS approaches in equal proportion (a balanced approach) as opposed to predominantly SS (6%) or Lean (27%). This is a very positive outcome, because if the majority of the respondents viewed their LSS project as a predominantly Lean (or SS) project, one can question the credibility of hypothesis test results. It seems inevitable that sometimes the concern of the quality/process improvement team is either reducing variation to increase process capability to a very high level (predominantly a SS problem) or eliminating waste and nonvalue adding activities (predominantly a Lean problem) to improve the bottom-line results of the company. A theory on LSS should fit such cases also, in the extreme.

The information in the two smaller pi-charts (counts of Lean, SS, and balanced across the two sectors considered) show that there is no difference between manufacturing and nonmanufacturing in terms of the problem-solving approach ($\chi^2 = 0.775$, $df = 2$, $p = 0.679$). This could be one sign that in terms of implementation complexity, there is no difference between manufacturing and nonmanufacturing.

### 7.3.3 Industry Representation

Table 7.2 classifies the respondents by industry based on the ANZSIC (Statistics, 2008; Trewin & Pink, 2006). One respondent did not respond to the relevant question. The main purpose of the information shown in Table 7.2 is to decide how best the 296 respondents should be partitioned for the purpose of answering RQ3. Should it be manufacturing, services, and other? Or manufacturing vs services? Or manufacturing vs nonmanufacturing? Merits and demerits of each option are discussed in turn.

158 respondents identified their company as manufacturing, but not services or other. Some respondents identified their company as manufacturing but also service (n = 2) or other (n = 2). This is acceptable because some manufacturing firms may want to position themselves as service-oriented firms or “other” firms. Many respondents belonging to the construction sector (five out of nine) identified their company as manufacturing, which for the purpose of this research, was considered valid, although construction of buildings, roads, structures, and other civil engineering outputs do not happen inside the four walls of a factory. Similar logic was applied for other somewhat uncertain selections (e.g., the accommodation and food services response as a response from manufacturing). To avoid confusion, column totals were considered for categorising the firms, for the purpose of answering RQ3.

Figure 7.8 shows the classification of the industries by sector. If all three sectors were considered, there is the advantage of using all 296 responses for hypothesis testing related to RQ3 (assuming the one who did not respond to the question on the sector belonged to “other” category), but one sector (“other” representing 24 responses) would be significantly underrepresented resulting in a high standard error for that sector. If the manufacturing and service dichotomy is used, the statistical analysis becomes simple but the 24 responses belonging to “other” category would be unutilised for hypothesis testing related to RQ3. If the manufacturing and nonmanufacturing dichotomy is used, the statistical analysis would not only be simple, but all the 296 responses would be utilised (assuming the one who did not respond to the question on the sector belonged to the "nonmanufacturing" category). The hypothesis relevant to RQ3 (H9) is shown section 6.3.

**Table 7.2 Classification of listed organisations by industries and sub-industries**

| Industry | Industry Classification | | | Total | Percentage |
|---|---|---|---|---|---|
| | Manufacturing | Service | Other | | |
| Manufacturing | 135 | 2 | 2 | 140 | 46.96% |
| Financial and Insurance Services | | 22 | | 22 | 7.43% |
| Health Care and Social Assistance | 2 | 15 | 5 | 22 | 7.43% |
| Other Services | 3 | 11 | 8 | 22 | 7.43% |
| Transport, Postal and Warehousing | 2 | 9 | 2 | 13 | 4.39% |
| Public Administration and Safety | | 12 | | 12 | 4.05% |
| Professional, Scientific and Technical Services | 1 | 10 | | 11 | 3.72% |
| Construction | 5 | 1 | 3 | 9 | 3.04% |
| Accommodation and Food Services | 1 | 7 | | 8 | 2.70% |
| Information Media and Telecommunications | | 8 | | 8 | 2.70% |
| Administrative and Support Services | | 7 | 2 | 9 | 3.04% |
| Education and Training | 1 | 3 | 3 | 7 | 2.36% |
| Mining | 3 | 1 | 1 | 5 | 1.69% |
| Agriculture, Forestry and Fishing | 3 | 1 | | 4 | 1.35% |
| Electricity, Gas, Water and Waste Services | 1 | 2 | | 3 | 1.01% |
| Retail Trade | 1 | 1 | | 2 | 0.68% |
| Grand Total | 158 | 112 | 26 | 296 | |

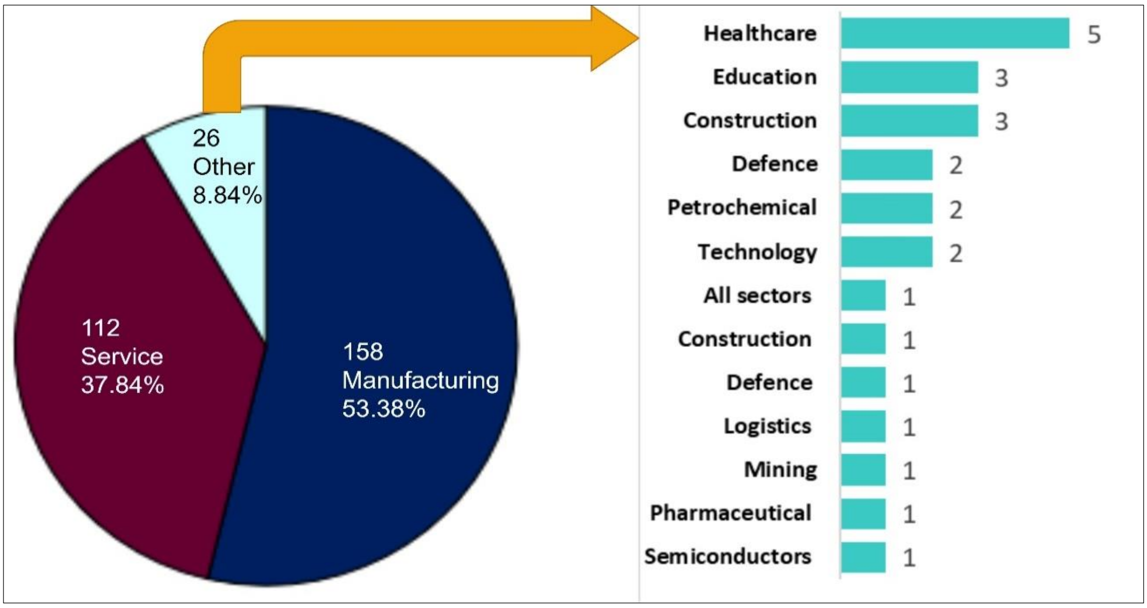



**Figure 7.8 Classification of industries based on sector**

### 7.3.4 Organisational Profile

Figure 7.9 classifies organisations of the respondents by size. The classification implies that the application of LSS methodologies is more prevalent in larger organisations (less than 10% belonged to the SME category of less than 250 employees). Hypothesis test results showed that size of the organisation is not a factor that effects LSS Project Execution as well as LSS Project Performance. The choice of the quality/process improvement approach (Lean, SS, Balanced) to suit a particular quality/process improvement problem is up to the organisation to decide.

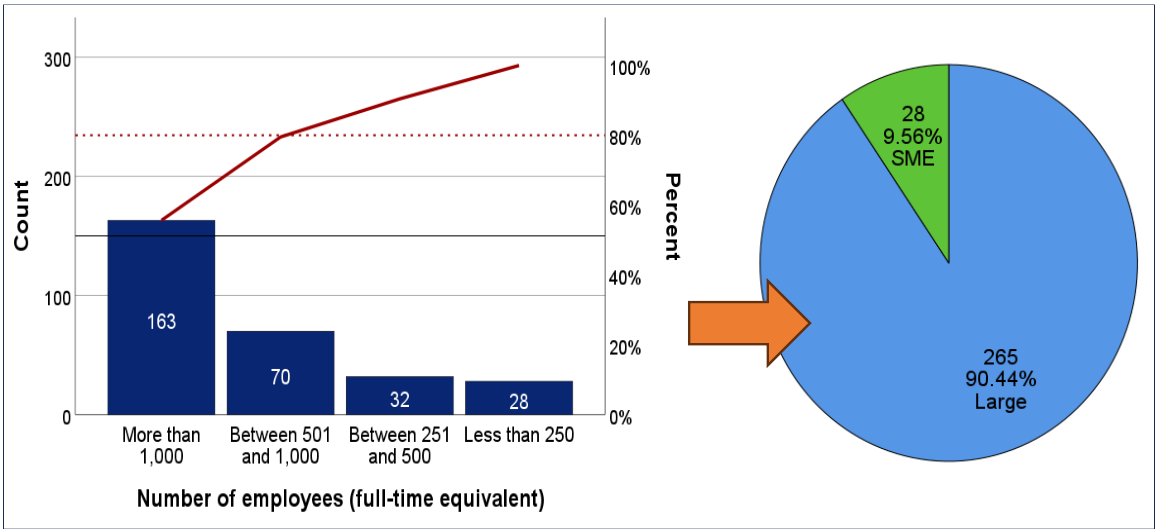



**Figure 7.9 Organisational size and sector representation**

Figure 7.10 classifies organisations of the respondents by their level of LSS maturity. Only a small proportion of organisations (7.09%; 21/296) had less than one year of experience in applying LSS; these organisations can be treated as inexperienced organisations from an LSS application standpoint, but it could be possible that these organisations are new organisations that do not have much of a history behind them. The remaining 265 organisations were considered as sufficiently experienced, for the purpose of this study. The question is whether the responses of the 21 respondents who belonged to inexperienced organisations should be discarded when testing the researcher's model (hypotheses). Since the unit of the analysis of the study is a single LSS project, it was decided that the 21 responses concerned should not be discarded.

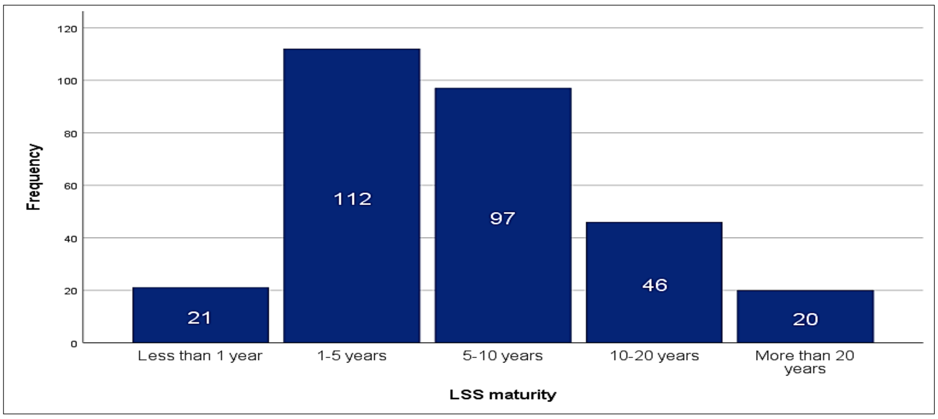



**Figure 7.10 LSS maturity of the organisations**

Given the distribution of the LSS maturity levels, it was examined whether the two factors LSS maturity and size of the organisations are correlated. Table 7.3 presents raw data pertaining to cross tabulations. The data in Table 7.3 suggest that larger organisations tend to be more mature than smaller organisations, suggesting a positive association between the two factors. The Chi squared test ($\chi 2 = 32.888$, $df = 16$, $p = 0.008$) provided more support towards this claim. In any case this association does not affect hypothesis test results.

**Table 7.3 LSS maturity level and the size of the organisation**

| | | | **Size of the Organisation: Number of full-time equivalent employees and percentages** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Less than 250 | Between 251 and 500 | Between 501 and 1,000 | More than 1,000 | Total |
| LSS maturity | Less than 1 year | Count | 3 | 3 | 6 | 8 | 21 |
| | | % within Number of employees | 10.70% | 9.40% | 8.60% | 4.90% | 7.10% |
| | 1-5 years | Count | 15 | 19 | 27 | 51 | 112 |
| | | % within Number of employees | 53.60% | 59.40% | 38.60% | 31.30% | 37.80% |
| | 5-10 year | Count | 7 | 5 | 29 | 54 | 97 |
| | | % within Number of employees | 25.00% | 15.60% | 41.40% | 33.10% | 32.80% |
| | 10-20 years | Count | 1 | 3 | 6 | 36 | 46 |
| | | % within Number of employees | 3.60% | 9.40% | 8.60% | 22.10% | 15.50% |
| | More than 20 years | Count | 2 | 2 | 2 | 14 | 20 |
| | | % within Number of employees | 7.10% | 6.30% | 2.90% | 8.60% | 6.80% |
| | Total | Count | 28 | 32 | 70 | 163 | 296 |
| | | % within Number of employees | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% |

***Note:*** Highlighted areas explain most of LSS maturity level contribution

### 7.3.5 Deployment of LSS: Methodology and Tools

Figure 7.11 classifies LSS projects based on the methodology and tools being used (manufacturing and nonmanufacturing data are also shown separately). Of the 289 responses to the relevant question on classification, 195 (67.47%) seem to have followed the DMAIC methodology for their project, of whom 75 have used complex statistical tools such as statistically designed experiments, while 120 have used simpler statistical tools such as control charts. This implies that a SS flavour (statistical thinking) was present in many projects, although many did not want to label their project as a predominantly SS project (section 7.3.2). Among 94 projects (32.53%) that did not use the DMAIC methodology, 69 seem to have used basic lean approaches to achieve their project deliverables. The Chi-squared test suggested that there is no association between the LSS methodology (treated as a five-level factor corresponding to the five classifications shown in Figure 7.11) and LSS maturity ($\chi2 = 23.303$, $df = 20$, $p = 0.274$). The Chi-squared test also suggested that although there is an apparent increase in the use of DMAIC methodology in manufacturing, when taking the types of LSS deployment as a whole, there is no difference between manufacturing and nonmanufacturing ($\chi2 = 2.020$, $df = 4$, $p = 0.732$). Note that the data in the blank category were merged with the data in the "Other" category to meet the expected cell out > 5 criterion for the Chi-squared test.

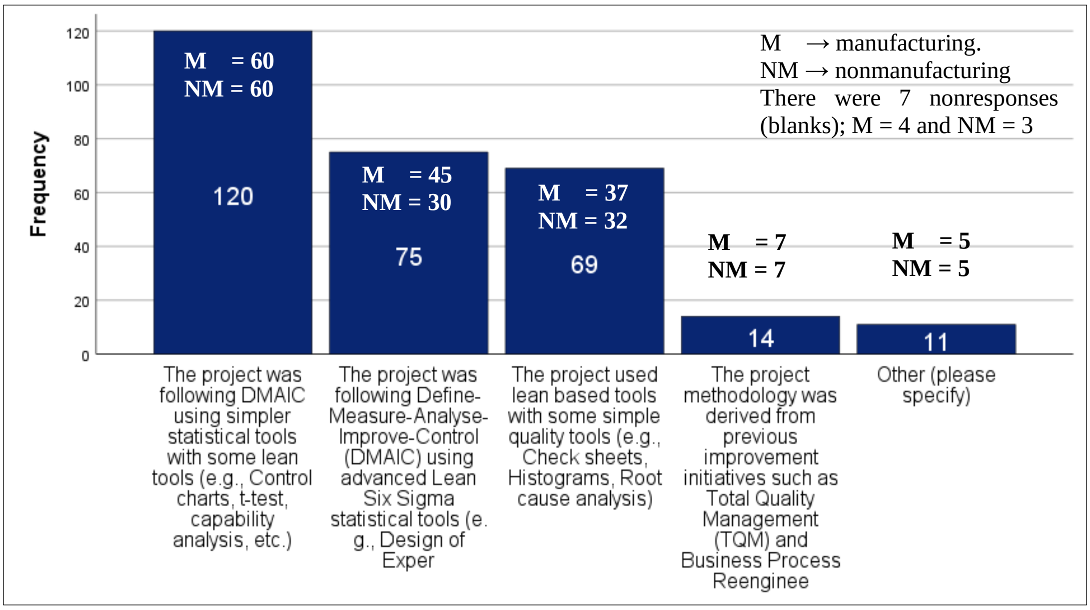



**Figure 7.11 Classification of LSS projects based on the methodology and tools being used**

Figure 7.12 classifies the respondents by the role they played in the LSS project. 290 respondents responded to the relevant question. Of these, 142 (48.97%) have played the role of a Black Belt or Master Black Belt. Interestingly 39 respondents (13.2%) were not able to identify themself as a person who played a specific role in the project, suggesting that these people were included in the LSS project team because they possessed domain knowledge that was deemed necessary for the project. It could be possible that some of these respondents do have either a GB or BB certification.

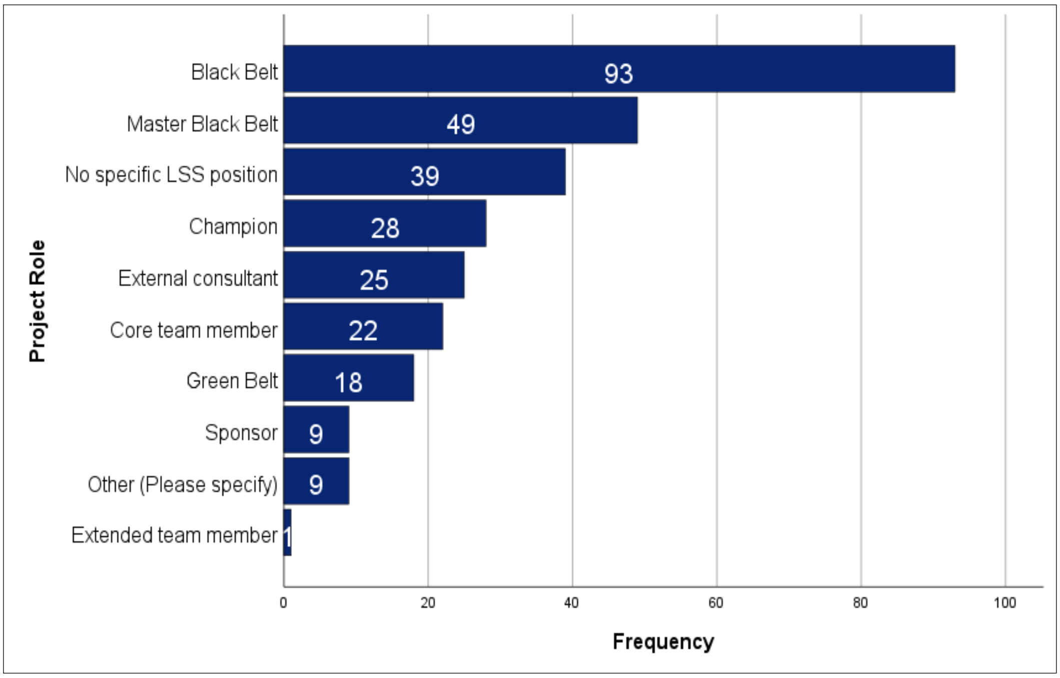



**Figure 7.12 LSS project role of respondents**

Figure 7.13 depicts the distribution of project duration, based on the 296 responses received for the relevant classification question. Descriptive statistics shown in Figure 7.13 suggests that project duration is 24 weeks for many projects. For example, the first quartile falls at 16 weeks (4 months), which can assume to be a reasonable time duration for basic level LSS projects to last. Figure 7.13 shows that as many as 117 projects (39.53%) took 15 to 25 weeks to complete. There was a solitary project that belongs to the 235-245 weeks range, which has deemed possible (e.g., delay in the arrival of a new machine or equipment); there were 13 LSS projects with a duration of 5 weeks or less, so it is questionable whether they were projects. It was verified that all these 13 LSS projects used basic lean/quality tools (Figure 7.11). Therefore, it was decided that the 13 cases relevant to this basic level of project should not be discarded at hypothesis testing stage.

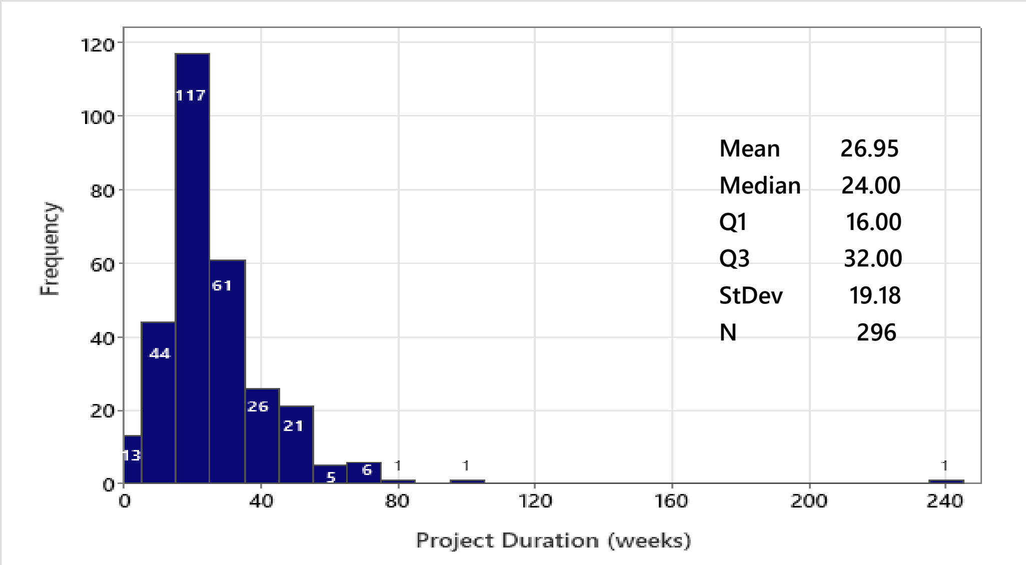



**Figure 7.13 Distribution of total project duration in weeks**

## 7.4 Data Screening and Preliminary Analysis

Screening raw data includes reviewing, verifying, and cleaning the data to ensure that the data are suitable for statistical inference. Data cleaning entails detecting and correcting data mistakes, inconsistencies, and anomalies such as missing values, outliers, or duplicate information. Hair Jr et al. (2017) and Kline (2016) highlight the importance of data screening/cleaning for partial least squares structural equation modelling (PLS-SEM) and covariance structural equation modelling methods respectively. Hair Jr et al. (2017) assert that although the PLS-SEM method does not rely on parametric assumptions such as the normal distribution of measurement scores, PLS-SEM results will still be sensitive to outliers, and it is necessary to exclude outliers from the data analysis. No outliers were found in the indicator scores and the few missing values were dealt with appropriately (details in section 7.4.1).

### 7.4.1 Dealing with Missing Values

Figure 7.14 shows the number and percentage of missing variables, cases, and individual cells for the 45 indicator variables (sometimes referred to "as indicated" by the researcher) that are relevant for theory testing via PLS-SEM. 19 out of 45 indicator variables returned missing values, as shown in the Variables pie chart (left chart). Among the 296 cases (data rows), 33 (11.15%) contained at least one missing value, as shown in the Cases pie chat (middle chart). The Values pie chart (the right chart) shows that out of the 13,320 values expected (consisting of 296 cases on 45 indicator variables, hence 296*45) only 36 were absent, which is only 0.27%). The PLS-SEM algorithm was prompted to replace the missing values with the mean scores of the indicators.

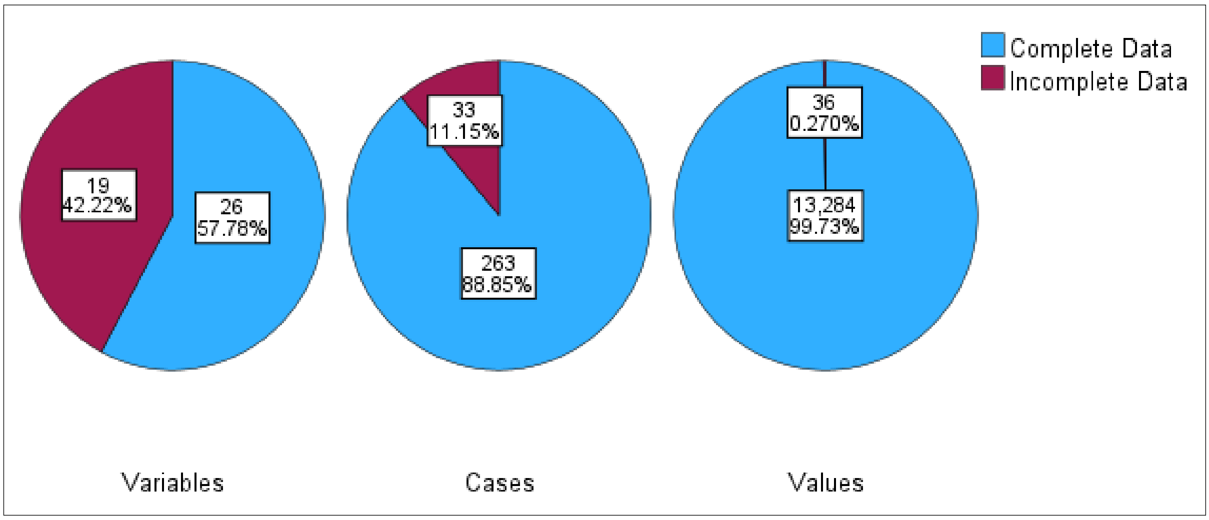



**Figure 7.14 Overall summary of missing values for the 45 indicators**

### 7.4.2 Descriptive Statistics of the 45 Indicators

Indicators of theoretical constructs form the basis of hypothesis testing in the sense of such things as construct reliability and validity determination, where these indicators dictate what the scores of the theoretical constructs ought to be and what the hypothesised theoretical relationships are. Therefore, it is important to know the location (central tendency) of the scores of each indicator and the dispersion of the scores. For central tendency of data, the mean and the median were considered, while for the dispersion, the standard deviation and interquartile range were considered. Additionally, the minimum and maximum score were also considered as to whether these two extremes indeed represent extreme values (outliers). The details are shown in Table 7.4. Highlighted in red are the indicators that return a mean score ≥6.0. On average, high scores represent an area of strength for the organisations represented by the respondents. In contrast, the lower-scoring areas emphasise improvement is needed.

**Table 7.4 Measures of central tendency and dispersion for the 45 indicator scores**

| Item | Mean | Median | Standard Deviation (SD) | Inter Quartile Range | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LE1 | 5.56 | 6.00 | 1.42 | 1.00 | 1 | 7 |
| LE2 | 5.65 | 6.00 | 1.39 | 2.00 | 1 | 7 |
| LE3 | 5.81 | 6.00 | 1.32 | 1.00 | 1 | 7 |
| LE4 | 5.69 | 6.00 | 1.43 | 2.00 | 1 | 7 |
| CUL1 | 5.38 | 6.00 | 1.22 | 1.00 | 1 | 7 |
| CUL2 | 5.61 | 6.00 | 1.08 | 1.00 | 1 | 7 |
| CUL3 | 5.45 | 6.00 | 1.38 | 1.00 | 1 | 7 |
| CUL4 | 5.73 | 6.00 | 1.23 | 2.00 | 1 | 7 |
| CUL5 | 5.53 | 6.00 | 1.23 | 1.00 | 1 | 7 |
| CUL6 | 5.56 | 6.00 | 1.27 | 1.00 | 1 | 7 |
| CUL7 | 5.94 | 6.00 | 1.21 | 2.00 | 1 | 7 |
| CUL8 | 5.81 | 6.00 | 1.22 | 2.00 | 1 | 7 |
| CUL9 | 5.85 | 6.00 | 1.33 | 1.00 | 1 | 7 |
| CUL10 | 5.49 | 6.00 | 1.26 | 1.00 | 1 | 7 |
| CUL11 | 5.07 | 5.00 | 1.33 | 2.00 | 1 | 7 |
| CUL12 | 5.64 | 6.00 | 1.24 | 1.00 | 1 | 7 |
| CUL13 | 5.51 | 6.00 | 1.17 | 1.00 | 1 | 7 |
| CUL14 | 5.43 | 6.00 | 1.24 | 1.00 | 1 | 7 |
| PRIN1 | 6.16 | 6.00 | 0.79 | 1.00 | 3 | 7 |
| PRIN2 | 5.78 | 6.00 | 1.19 | 2.00 | 2 | 7 |
| PRIN3 | 6.11 | 6.00 | 0.91 | 1.00 | 2 | 7 |
| PRIN4 | 5.74 | 6.00 | 1.06 | 2.00 | 2 | 7 |
| PRIN5 | 6.06 | 6.00 | 0.98 | 1.00 | 1 | 7 |
| PRIN6 | 5.97 | 6.00 | 1.07 | 1.00 | 1 | 7 |
| PREX1 | 6.00 | 6.00 | 0.84 | 1.00 | 2 | 7 |
| PREX2 | 5.41 | 6.00 | 1.30 | 1.00 | 1 | 7 |
| PREX3 | 5.81 | 6.00 | 1.14 | 2.00 | 1 | 7 |
| PREX4 | 6.03 | 6.00 | 0.88 | 1.00 | 2 | 7 |
| PREX5 | 5.47 | 6.00 | 1.30 | 1.00 | 1 | 7 |
| PREX6 | 5.36 | 6.00 | 1.33 | 1.00 | 1 | 7 |
| PREX7 | 5.82 | 6.00 | 0.87 | 1.00 | 3 | 7 |
| PREX8 | 5.94 | 6.00 | 0.85 | 1.00 | 1 | 7 |
| PRRISK1 | 4.17 | 4.00 | 1.54 | 2.00 | 1 | 7 |
| PRRISK2 | 4.42 | 5.00 | 1.49 | 3.00 | 1 | 7 |
| PRRISK3 | 4.24 | 4.00 | 1.71 | 3.00 | 1 | 7 |
| PRRISK4 | 4.51 | 5.00 | 1.74 | 3.00 | 1 | 7 |
| PRRISK5 | 4.42 | 5.00 | 1.81 | 3.00 | 1 | 7 |
| LSSPER1 | 5.97 | 6.00 | 0.99 | 1.00 | 1 | 7 |
| LSSPER2 | 6.12 | 6.00 | 0.86 | 1.00 | 1 | 7 |
| LSSPER3 | 5.76 | 6.00 | 1.18 | 2.00 | 1 | 7 |
| LSSPER4 | 5.82 | 6.00 | 1.10 | 2.00 | 1 | 7 |
| LSSPER5 | 4.82 | 5.00 | 1.67 | 2.00 | 1 | 7 |
| LSSPER6 | 5.99 | 6.00 | 0.92 | 1.00 | 2 | 7 |
| LSSPER7 | 5.94 | 6.00 | 0.96 | 1.00 | 1 | 7 |

| Item | Mean | Median | Standard Deviation (SD) | Inter Quartile Range | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LSSPER8 | 6.11 | 6.00 | 0.86 | 1.00 | 3 | 7 |

In normally distributed data (not a requirement in PLS-SEM), 95.44% of the observations are expected to be within mean $\pm$ 2SD range while 99.73% of the observations are expected to be within mean + 3SD range. Using this rule of thumb, the maximum score of 7 is clearly not an outlier. Besides, in top performing projects (many respondents may have responded to the questionnaire with their flagship project or the most successful project in mind) a respondent strongly agreeing to a statement on any aspect of the project (e.g., Leadership Engagement), hence returning a score of 7 (Figure 7.15) should not be uncommon. . The question to consider is whether a minimum score of 1 (the respondent strongly disagreeing to a statement) is an outlier. To answer this question, the researcher considered the count of 1.0 scores as well as the distribution of scores. As an example, the distribution of scores of LE1 is shown in Figure 7.15. Only eight respondents (2.70%) strongly disagreed to the statement "leadership was able to communicate effectively throughout the project, with a solid communication plan" (the statement corresponding to LE1). Given the measurement system used in the study, the eight scores of 1 were not treated as outliers[24]. Chances are that on another day, some of the respondents would have chosen the disagree option (= 2) as opposed to the strongly disagree option (= 1) they chose at the time of responding. This logic was extended to other indicators, and it was determined that there were no univariate outliers to be considered.

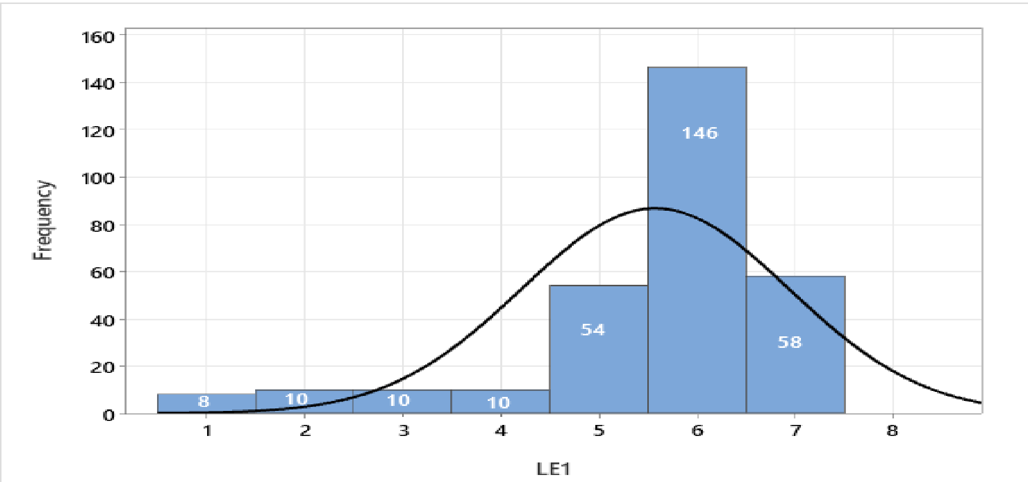



**Figure 7.15 Distribution of 296 scores of the indicator LE1**

[24] Social science measurement systems such as a Likert scale cannot expect the levels of precision that are applied in quality engineering, such as the precision expected in measurement gauges.

The distribution of some indicator scores (e.g., LE1 as evidenced in Figure 7.15) did not track the bell curve (the theoretical normal distribution based on the calculated mean and the standard deviation), but this parametric requirement in statistical inferencing does not become a requirement in PLS-SEM because, as mentioned before (section 4.7.1), inferential statistics is derived in PLS-SEM using a resampling method (in SmartPLS, bootstrapping).

### 7.4.3 Testing Common Method Bias

As explained in Chapter 3, CMB is a well-known problem in self-administered surveys. If present, CMB would adversely affect PLS-SEM test results. CMB occurs when the variance in data is driven by a shared method of measurement rather than the actual constructs studied (Conway & Lance, 2010; MacKenzie & Podsakoff, 2012). This can result in spurious findings, where relationships among constructs are exaggerated or distorted, leading to spurious results. To avoid inaccurate results and flawed conclusions, it is important to be aware of the possibility of CMB when analysing survey data (Conway & Lance, 2010). Two tests for CMB were performed: Harman's single factor test (Podsakoff et al., 2003) and the full collinearity test (Kock, 2015; Kock & Lynn, 2012).

***Harman's single-factor test***

Harman's single factor test is a basic test used to examine whether CMB might be present (Podsakoff *et al.*, 2003). Harman's single factor criteria states that CMB exists if only one component is extracted (components with Eigenvalue > 1.0) in the initial factor solution on survey questions via principal component analysis (PCA), and that this component (first principal component) extracts a considerable proportion of total variability of the measures in the un-rotated factor solution (Aguirre-Urreta & Hu, 2019; Podsakoff et al., 2012). The lower bound threshold for a considerable proportion is generally considered to be ≥ 50% (Kock, 2020), but the researcher notes that sometimes a more conservative figure of > 40% has also been used (Zhou Hao, 2004), which is reasonable because 50% represents a very high proportion for a single factor to extract from the total variability of 45 indicators when the researcher is theorising that her 45 indicators actually belong to six factors or constructs (see the theoretical model shown in Figure 7.19).

Results shown in Table 7.5 clearly indicate that, unsurprisingly, so many factors emerge based on Eigenvalue > 1.0 criteria (often known as the Kaiser criteria), and that the first factor extracts only a modicum of total variability (17.68%) of the 35 indicators[25]. Thus, it is declared that based on Harman's single factor test, the indicator scores are free from CMB.

**Table 7.5 Unrotated factor solution to be considered for Harman's single factor test**

| Component (Factor) | Eigenvalue | % of Total Variance | Cumulative % |
|---|---|---|---|
| 1 | 7.955 | 17.678 | 17.68 |
| 2 | 2.913 | 6.472 | 24.15 |
| 3 | 2.212 | 4.915 | 29.07 |
| 4 | 1.767 | 3.927 | 32.99 |
| 5 | 1.702 | 3.783 | 36.78 |
| 6 | 1.521 | 3.381 | 40.16 |
| 7 | 1.432 | 3.183 | 43.34 |
| 8 | 1.325 | 2.945 | 46.28 |
| 9 | 1.264 | 2.808 | 49.09 |
| 10 | 1.165 | 2.59 | 51.68 |
| 11 | 1.132 | 2.515 | 54.20 |
| 12 | 1.114 | 2.476 | 56.67 |
| 13 | 1.064 | 2.365 | 59.04 |
| 14 | 1.027 | 2.281 | 61.32 |
| 15 | 1.022 | 2.272 | 63.59 |
| 16 | 1.014 | 2.254 | 65.85 |
| 17 | 1.004 | 2.231 | 68.08 |

***Note:*** Extraction method- PCA
The Kaiser criterion (Kaiser, 1960) of Eigenvalue > 1.0 was used in extracting factors.

### *Full Collinearity Test*

Harman's single-factor test is based on the shared variance idea applied in psychometrics, where it is expected that measures belonging to a particular construct should share much of the variability of their construct (Diamantopoulos et al., 2008; Petter et al., 2007). This conceptualisation will not hold true when a researcher uses formative constructs (Diamantopoulos et al., 2008; Hair Jr et al., 2017; Petter et al., 2007). Since the researcher has six indicators belonging to the formative construct "Project Initiation", the researcher used the

[25] One may question why as many as 17 factors emerged as factors having Eigenvalue > 1.0 (the Kaiser criteria) in the unrotated factor solution. Two reasons can be given for this. Firstly, out of the 17 factors only about the first 11 factors can be treated as factors in contention (the screen plot is not shown as the focus here is not PCA but CMB). Secondly, and perhaps more importantly, the researcher has six indicators which are formative measures (project initiation is a formative constructs) and one does not expect these six indicators to share a common variance.

full collinearity assessment approach prescribed by Kock (2015), to provide evidence of absence of CMB. The term "full collinearity" is used by Kock & Lynn (2012) to emphasise the fact that typical or classic collinearity assessment used in multiple linear regression analysis (Kock & Lynn use the term vertical collinearity also, to mean classic collinearity) is not sufficient to examine overlapping meanings in SEM because there are multiple blocks of predictor-response relationships between constructs, and therefore, the collinearity assessment within each block must extend to cover all the predictor constructs in all the blocks (Kock and Lynn use the term lateral collinearity to mean this)[26]. The argument of Kock and Lynn is that the presence of Lateral collinearity suggests that indicators of theoretically distinguishable constructs have been misunderstood by the respondents in a survey to a different underlying concept, hence CMB.

The procedure used below to conduct the full collinearity test follows the exact same procedure prescribed by Kock & Lynn (2012) in pp 578-579 involving a random dummy variable. Here the term random dummy variable means any random variable that is not part of the theory. The idea is to regress all the six theoretical constructs against any random dummy variable to demonstrate that the VIF of each of the six constructs are less than 3.3 to imply absence of collinearity (Kock & Lynn, 2012). Figure 7.16 shows the regression model used to examine lateral collinearity (and thereby CMB), where the label Random refers to a random number (generated in Excel) used in SmartPLS, merely for the purpose of determining the VIF value of each predictor. The reader should not attempt to interpret the regression coefficients of the six predictor constructs nor the $R^2$ value of 0.041 as shown in Figure 7.16 as these do not have a substantive interpretation. This is because one does not expect the theoretical constructs to predict a random variable (the sole purpose of this procedure is to obtain the VIF values of the predictors, which are also theoretical constructs). Table 7.6 shows the VIF values of the predictors, which are the focus of this analysis. All the VIF values are much less than the 3.3, suggesting no lateral collinearity, and hence, an absence of CMB, based on the full collinearity test.

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[26] In the researcher's model (Figure 7.21) contains four predictor-response blocks. CI Culture is predicted by Leadership Engagement (say block 1); LSS Project Initiation is predicted by Leadership Engagement and CI Culture (say block 2); LSS Project Execution is predicted by Leadership Engagement, LSS Project Initiation, and CI Culture (say block 3); finally, LSS Project Performance is predicted by LSS Project Execution, Project Residual Risks, and the interaction term LSS Project Execution*Project Residual Risks (say block 4).

**Table 7.6 Collinearity diagnostics for the model examining lateral correlation**

| Predictor (see Figure 7.16) | VIF |
|---|---|
| CI Culture | 1.65 |
| LSS Project Execution | 1.03 |
| Leadership Engagement | 1.41 |
| LSS Project Initiation | 1.14 |
| Project Performance | 1.13 |
| Project Residual Risks | 1.13 |

Now that the indicator data have been fully examined and CMB has been excluded, in the next section, the researcher focuses her attention on testing the theoretical model, which begins with examining the validity and reliability of the theoretical constructs (i.e., evaluating the measurement model).

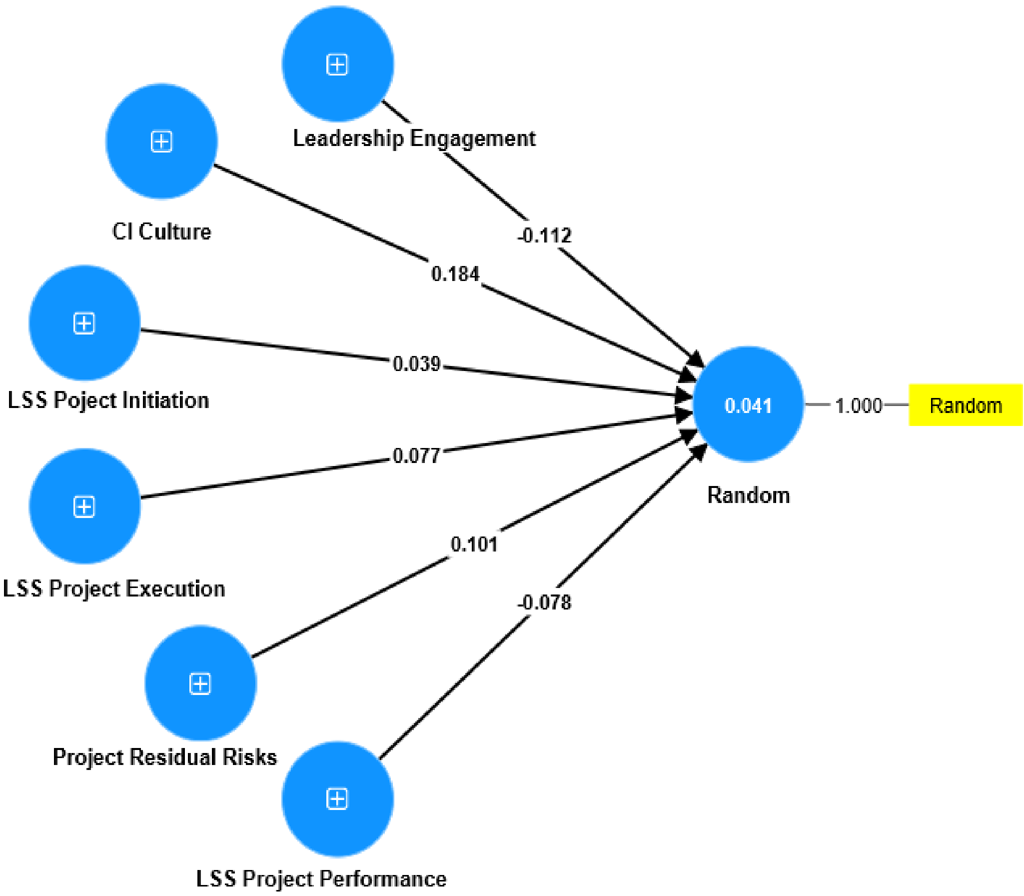


**Figure 7.16 Regression model for testing lateral collinearity for examining CMB**

## 7.5 Evaluation of the Measurement Model

In SEM in general and with PLS-SEM in particular, it is imperative to determine whether a particular construct should be theorised as formative or reflective. Reflective or formative, each construct has a measurement theorisation. The theorisation of constructs as a whole is represented both graphically and statistically as the measurement model (also known as the outer model), while the theorisation of the relationships between the constructs themselves is represented graphically and statistically as the structural model (also known as the inner model) (Hair et al., 2022; Henseler, 2010).

A formative construct is a construct whose meaning is formed by its indicators — a construct that is not common in many disciplines, in part because a formative measurement conceptualisation defies the scientific notion (conventional wisdom) of a concept existing irrespective of its indicators (Bollen & Lennox, 1991). From a measurement perspective, a formative construct is based on the theorisation that that construct is caused by its indicators (Bollen & Lennox, 1991; Diamantopoulos et al., 2008; Hair Jr et al., 2017; Petter et al., 2007). A reflective construct (a traditional construct representing a scientific concept) on the other hand is based on the theorisation that indicators are mere manifestations of the construct and thus the construct is the cause and indicators are the effects of that construct (Bollen & Lennox, 1991; Diamantopoulos et al., 2008; Hair Jr et al., 2017).

In the researcher's model, Leadership Engagement is a concept that manifests as effective communication, fostering a learning environment, empowering the team, and actively participating in evaluations. As such Leadership Engagement exists as a naturally occurring concept. CI culture was considered a naturally occurring phenomenon in quality improvement; the researcher used 13 different indicators[27] to reflect many facets of the concept. Likewise, the researcher argues that all but the construct "LSS Project Execution" are naturally occurring concepts and hence should be represented as reflective constructs. Project execution is better understood as a formative concept because certain well-defined activities—effective resource allocation, team coordination, risk management, and communication—are needed to execute

[27] 13 indicators were used because organizational culture represents Group Culture, Development Culture, Rational Culture, and Hierarchical Culture Cameron, K. S., & Quinn, R. E. (2011). *Diagnosing and changing organizational culture: Based on the competing values framework*. John Wiley & Sons.

an LSS project. Chapter 4 section 4.7.1 explains the PLS-SEM process for measurement model evaluation and Figure 4.15 shows what aspects of the measurement model (outer model) have to be tested to establish the validity of the measurement system.

### 7.5.1 Assessment of Reflective Measurement Model

The reflective measurement model was established by examining convergent validity, reliability (internal consistency reliability), and discriminant validity. Convergent validity should be established to demonstrate that multiple indicators of a specific construct are indeed consistent. Internal consistency reliability needs to be established to demonstrate that indicators of a reflective construct do relate to one another (in a correlational sense) for the construct's measurement scale to be deemed reliable (Gefen & Straub, 2005; Nunnally & Bernstein, 1994). Finally, discriminant validity needs to be established to assure that a construct is a distinct construct rather than simply an overlap of another construct (Hair et al., 2019; Knol et al., 2018; Yurim Zagloel et al., 2018).

***Convergent Validity***

As the name implies, convergent validity refers to extent to which measures (indicators) of a measurement scale relate to the underlying construct (Gefen & Straub, 2005). Conversely it can be said that convergent validity is the "extent to which a construct converges to explain" the variability of its indicators (Hair *et al.*, 2019, p. 9). This second notion of convergent validity is examined by looking at the AVE of the construct, from its measures. The requirement for convergent validity is an AVE > 0.50 (Hair Jr *et al.*, 2017; Muraliraj *et al.*, 2020; Petter *et al.*, 2007). The first notion of convergent validity (i.e., the relatedness of the construct and individual measures) is examined by looking at the loadings of the measures[28] and establishing that they are strong (> 0.60 was used). Results reported in columns 3 and 4 of Table 7.7 show that reflective constructs pass convergent validity thresholds. PRIN3 and LSSPER5 were excluded because inclusion of these items weakened the AVE (AVE of PRIN with PRIN3 = 4.950; AVE of LSSPER with LSSPER5 = 0.496)

[28] A loading of a measure is the correlation between the measure and its construct.

***Scale Reliability***

The measurement scales of latent variables (constructs) need to be evaluated for their reliability, using Cronbach’s alpha coefficient, composite reliability coefficient $\rho_a$ and composite reliability coefficient $\rho_c$. Composite reliability coefficient $\rho_c$ is a coefficient used in SmartPLS software to mean the composite reliability (CR) coefficient defined by Jöreskog (1971), which is the variability of true scores of the indicators divided by the variability of the observed scores of the indicators (Peterson & Kim, 2013). Here, the true score means, the observed score of a measurement minus the measurement error, as estimated statistically. Composite reliability coefficient $\rho_c$ is deemed a liberal (upper-bound) estimate of scale reliability, relative to the Cronbach alpha coefficient (next paragraph), which is deemed as a conservative (lower bound) estimate of scale reliability (Hair *et al.*, 2019). For this reason, Hair *et al.* (2019) recommend using the composite reliability coefficient $\rho_a$, which is a CR estimate adjustment that is neither liberal nor conservative. Cronbach’s alpha examines whether the indicators (measures) of a scale are sufficiently intercorrelated to be treated as a reliable and internally consistent scale (Nunnally, 1978). Minimal acceptable Cronbach’s alpha values for scales used in exploratory research and established research are 0.60 and 0.70 respectively, according to Nunnally (1978). These guidelines have also been extended for research involving PLS-SEM (e.g., see Hair *et al.*, 2019).

The results reported in Table 7.7 clearly indicate that the measurement scales of all five (reflective) constructs easily exceed the 0.70 threshold for scale reliability (all $\rho_a$ and Cronbach's alpha > 0.70).

**Table 7.7. Internal consistency, reliability, and convergent validity for model**

| [1] **Construct** | [2] **Item Code** | [3] **Loadings** | [4] **AVE** | [5] **Cronbach's alpha** | [6] **CR (*rho_a*)** | [6] **CR (*rho_c*)** |
|---|---|---|---|---|---|---|
| Leadership Engagement (LE) | LE1 | 0.844 | 0.701 | 0.858 | 0.864 | 0.904 |
| | LE2 | 0.819 | | | | |
| | LE3 | 0.834 | | | | |
| | LE4 | 0.851 | | | | |
| CI Culture (CI CUL) | CUL1 | 0.604 | 0.541 | 0.934 | 0.932 | 0.942 |
| | CUL2 | 0.671 | | | | |
| | CUL3 | 0.808 | | | | |
| | CUL4 | 0.821 | | | | |
| | CUL5 | 0.812 | | | | |
| | CUL6 | 0.754 | | | | |
| | CUL7 | 0.762 | | | | |
| | CUL8 | 0.798 | | | | |
| | CUL9 | 0.633 | | | | |
| | CUL10 | 0.692 | | | | |
| | CUL11 | 0.652 | | | | |
| | CUL12 | 0.757 | | | | |
| | CUL13 | 0.752 | | | | |
| | CUL14 | 0.741 | | | | |
| LSS Project Initiation (PRIN) | PRIN1 | 0.651 | 0.529 | 0.779 | 0.808 | 0.849 |
| | PRIN2 | 0.754 | | | | |
| | PRIN4 | 0.728 | | | | |
| | PRIN5 | 0.732 | | | | |
| | PRIN6 | 0.767 | | | | |
| LSS Performance (LSSPER) | LSSPER1 | 0.706 | 0.555 | 0.867 | 0.870 | 0.897 |
| | LSSPER2 | 0.736 | | | | |
| | LSSPER3 | 0.672 | | | | |
| | LSSPER4 | 0.742 | | | | |
| | LSSPER6 | 0.765 | | | | |
| | LSSPER7 | 0.817 | | | | |
| | LSSPER8 | 0.767 | | | | |
| Project Residual Risks (PRRISK) | PRRISK1 | 0.724 | 0.585 | 0.829 | 0.850 | 0.875 |
| | PRRISK2 | 0.804 | | | | |
| | PRRISK3 | 0.812 | | | | |
| | PRRISK4 | 0.810 | | | | |
| | PRRISK5 | 0.664 | | | | |

***Note:*** PRIN3 and LSSPER5 were excluded as the inclusion of these items impacted the AVE.

### *Discriminant Validity*

Latent variable analysis methods such as structural equation modelling (PLS-SEM or CB-SEM) require the establishment of discriminant validity (Byrne, 2016; Shah & Goldstein, 2006). Discriminant validity is the extent to which constructs are empirically distinguishable based on how the measurement model has been specified (Gefen & Straub, 2005; Hair et al., 2019). Without establishing discriminant validity, researchers cannot be certain whether results confirming hypothesised structural paths are real or whether they are a result of statistical discrepancies. The heterotrait-monotrait (HTMT) ratio of correlations was used to assess the discriminant validity of the reflective measurement model. The thresholds (maximum allowable) for HTMT ratios are 0.90, when conceptually similar constructs are involved and 0.85 when such constructs are not involved (Henseler et al., 2015; Sarstedt et al., 2019). This approach suggested by Henseler et al. (2015) is currently regarded as the most robust criterion to examine discriminant validity (Hair et al., 2019; Henseler et al., 2015). The results shown in Table 7.8 clearly indicate that all ratios return values < 0.85, thus establishing discriminant validity.

**Table 7.8 The heterotrait-monotrait (HTMT) correlation ratio**

| Construct | BPER | CI CUL | PRIN | LE | PRRISK | PRRISK x PREX |
|---|---|---|---|---|---|---|
| **LSSPER** | | | | | | |
| **CI CUL** | 0.396 | | | | | |
| **PRIN** | 0.559 | 0.559 | | | | |
| **LE** | 0.34 | 0.678 | 0.462 | | | |
| **PRRISK** | 0.314 | 0.293 | 0.199 | 0.129 | | |
| **PRRISK x PREX** | 0.021 | 0.052 | 0.064 | 0.138 | 0.257 | |

Older publications apply Fornell-Larcker criterion (Fornell & Larcker, 1981) and still worse, loading-cross loading matrices as evidence of discriminant validity[29]. The researcher excludes such information here because there is no point in including tests that have now been proven to be less robust.

### 7.5.2 Assessment of the Formative Measurement Model

Based on the guidelines of Hair et al. (2022) and Diamantopoulos et al. (2008), the validity of the formative measurement model was established based on indicator collinearity diagnostics and the significance and relevance of formative indicators. The results (Table 7.9) show that indicator collinearity is not strong enough to return unstable estimates because the *VIF* values were < 3.3 for all the formative indicators, as required. In the subsequent step, bootstrapping

[29] Smart-PLS still reports outputs on Fornell-Larcker criterion as well as loading-cross loading matrices!

analysis was performed to assess significance of the weights. The results in Table 7.9 show that the weights of four indicators of the formative construct are significant and when the outer loadings are examined, all the indicators including the ones that were not significant for outer weight, showed that even these indicators are relevant when operationalising the formative construct PREX (for details of the procedure, see Hair et al., 2022, pp 140-152).

**Table 7.9 Collinearity, outer weights, and outer loading data for the formative construct LSS Project Execution (PREX)**

| **PLS-SEM algorithm** | | **Bootstrapping Results** | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **VIF (<5)** | | **Outer Weight** | ***p-value*** | **Outer Loading** | ***p-value*** |
| PREX1 | 1.592 | PREX1 -> PREX | 0.134 | 0.041* | 0.644 | <0.001* |
| PREX2 | 1.744 | PREX2 -> PREX | 0.301 | 0.001* | 0.784 | <0.001* |
| PREX3 | 1.676 | PREX3 -> PREX | 0.094 | 0.031* | 0.644 | <0.001* |
| PREX4 | 1.461 | PREX4 -> PREX | 0.177 | 0.059 | 0.554 | <0.001* |
| PREX5 | 1.438 | PREX5 -> PREX | 0.356 | <0.001* | 0.734 | <0.001* |
| PREX6 | 1.650 | PREX6 -> PREX | 0.112 | 0.099 | 0.649 | <0.001* |
| PREX7 | 1.790 | PREX7 -> PREX | 0.056 | 0.166 | 0.578 | <0.001* |
| PREX8 | 1.949 | PREX8 -> PREX | 0.22 | 0.078 | 0.695 | <0.001* |

**Notes:** Critical value for t > 1.96, and significance value for p* is < 0.05 (Hair et al., 2022)

## 7.6 Evaluation of the Structural Model and Hypothesis Test Results

Having demonstrated reliability and validity of the measurement models, in this section, the researcher focuses on testing her structural model. Figure 7.17 depicts the structural model, along with the estimated structural regression coefficients (path coefficients), the statistical significance of these coefficients (the p-values), and the $R^2$ of the endogenous constructs. The concerns/questions are as follows:

(i) Does the regression analysis support the hypothesised relationships in the structural model?

(ii) If the regression analysis does support the hypothesised relationships, what is the strength of each of the hypothesised relationships? And,

(iii) If a particular hypothesised relationship is not supported via the regression analysis, what is its statistical and practical implication?

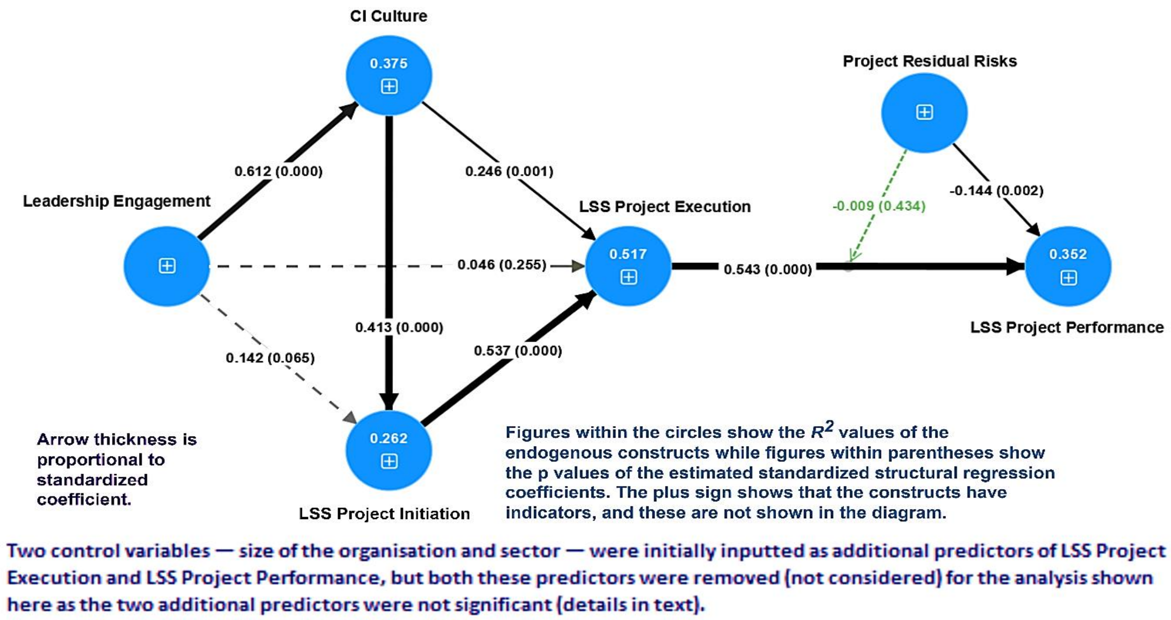


**Figure 7.17 Estimated model parameters of the structural model**

A structural model must be evaluated for possible collinearity issues (more technically precisely, vertical collinearity issues) since the path coefficients are estimated using (Ordinary least squares - OLS) a regression equation for each endogenous construct expressed as a function on its corresponding explanatory constructs (i.e., a regression equation for each block of constructs); strong correlations between explanatory constructs can bias the estimated regression coefficients and standard errors. The collinearity was examined via the *VIF* of each explanatory construct. Table 7.10 shows that VIF values are less than 3.3, which implies that there is no collinearity issue posing a threat to the adequacy of the model.

**Table 7.10 Collinearity statistics of inner model**

| Predictor | Response | VIF of the Predictor |
|---|---|---|
| Leadership Engagement | CI Culture | 1.000 |
| Leadership Engagement | LSS Project Initiation | 1.600 |
| CI Culture | LSS Project Initiation | 1.600 |
| Leadership Engagement | LSS Project Execution | 1.627 |
| CI Culture | LSS Project Execution | 1.826 |
| LSS Project Initiation | LSS Project Execution | 1.349 |
| LSS Project Execution | LSS Project Performance | 1.103 |
| Project Residual Risks | LSS Project Performance | 1.159 |
| Project Residual Risks x LSS Project Execution | LSS Project Performance | 1.109 |

Table 7.11 depicts the standardised structural regression coefficients (path coefficients), their statistical significance (*p-values*), and the localised Cohen's $f^2$ *effect* sizes. Based on Cohen's

guidelines (Cohen, 1992, p. 157), an $f^2 = 0.02$ signposts a small predictor-response effect, an $f^2 = 0.15$ signposts a medium predictor-response effect, while an $f^2 = 0.35$ signposts a large predictor-response effect, in relation to linear regression analysis. The results show that of the nine hypotheses being tested (the last two hypotheses being subparts of H8), six were supported by data ($p < 0.05$), with four relationships showing large effects.

**Table 7.11 Assessment of the structural model**

| **Hypothesis** | **Path coefficient-statistics** | | **Cohen's $f^2$ (Local)** | **Decision** |
|---|---|---|---|---|
| | Path coefficient ($\beta$) | *p-values* | | |
| H1: LE→PRIN | 0.142 | 0.065 | 0.08 | Not Supported |
| H2: LE→CICUL | 0.612 | < 0.001 | 0.60 | **Supported; LE** |
| H3: LE→PREX | 0.046 | 0.225 | 0.00 | Not Supported |
| H4: PRIN→PREX | 0.537 | < 0.001 | 0.44 | **Supported; LE** |
| H5: CICUL→PRIN | 0.413 | < 0.001 | 0.14 | **Supported; ME** |
| H6: CICUL→PREX | 0.246 | 0.001 | 0.07 | **Supported; SE** |
| H7: PREX→LSSPER | 0.543 | < 0.001 | 0.41 | **Supported; LE** |
| H8a: PRRISK→LSSPER | -0.144 | 0.001 | 0.03 | **Supported; SE** |
| H8b: PRRISK*PREX→LSSPPER | -0.009 | 0.434 | 0.00 | Not Supported |

SE: Small effect; ME – Medium effect; LE: Large effect

In the second step, attention is focused on indirect effects, mainly to make sense out of unsupported hypotheses on direct effects (shown as dashed lines in Figure 7.19). For example, although data failed to support H1 at 0.05 significance level (p = 0.065), LE could still have a significant effect on PRIN indirectly through the mediator CI Culture (see Figure 7.17 to visualise the mediating paths). Table 7.12 lists all the indirect relations, their effects, and significance (p-values). The results in Table 7.12 clearly indicate that all indirect paths are significant.

**Table 7.12 Total indirect effects**

| **Indirect Path** | **Indirect Effect** | ***p-value*** |
|---|---|---|
| CI CUL-> LSSPER | 0.248 | < 0.001 |
| CI CUL -> PREX | 0.221 | < 0.001 |
| PRIN-> LSSPER | 0.311 | < 0.001 |
| LE-> LSSPER | 0.216 | < 0.001 |
| LE-> PRIN | 0.240 | < 0.001 |
| LE-> PREX | 0.361 | < 0.001 |

In addition to the p-values of the structural regression coefficients, Figure 7.19 shows the p-values of the parameters of the measurement model (outer model). For the five reflective constructs, Figure 7.19 shows the p-values of the loadings (the arrows going out from a construct to its measures show that the construct is causing the variability of its indicators) while for the formative construct LSS Project Execution, what is shown in Figure 7.19 are the p-values of indicator weights (since the arrows point toward the construct, the variability of the construct can be explained by its indicators). It was these p values that were scrutinised first in the evaluation of a formative measurement model (section 7.5.2).

The reader should also note that the size of the organisation (represented by an interval scale variable having 4 intervals to represent the four size ranges < 250, 251-500, 501-1000, > 1000) and the sector (dummy coded taking manufacturing as the reference) were included as control variables (hence additional predictors) in predicting PREX and LSSPER. When control variables were included, for LSSPER, the $R^2$ increased from 0.362 to 0.364 while the coefficients of Size and Sector returned as -0.043 ($p$ = 0.177) and 0.019 ($p$ = 0.420) respectively. Likewise, for PREX the $R^2$ increased from 0.517 to 0.518 while the coefficients of Size and Sector returned as -0.012 ($p$ = 0.394) and 0.024 ($p$ = 0.399) respectively. The insignificance of the control variables was the reason why they were not considered in the analysis reported in the thesis.

### 7.6.1 Interpretation of the Role Being Played by LSS Project Residual Risk

Based on the estimated standardised structural regression coefficients (see Table 7.11 for the coefficients, which are presented as path coefficients), the relationship between LSS Project Execution, LSS Project Residual Risk and LSS Project Performance is as follows:

$$\mathbf{LSSPER = 0.543 * PREX - 0.144 * PRRISK - 0.009 * PREX * PRRISK} \qquad (7\text{-}1)$$

The above equation (7-1) is valid for standardised scores. A standardised score of -1 indicates a score that is 1 standard deviation below the mean, while a standardised score of +1 indicates a score that that is 1 standard deviation above the mean.

Figure 7.18 depicts the relationship between LSS Project Performance and LSS Project Execution for two levels of LSS Project Residual Risk (-1 could be treated as low residual risk and 1 can be treated as high residual risk). In other words, Figure 7.18 depicts the interaction plot for LSS Project Performance. The interaction plot was created using the equation 7-1 to better understand the role being played by LSS Project Residual Risk. The two nearly parallel lines indicate that LSS Project Residual Risk does not interact with LSS Project Execution (this should not come as a surprise because the results in Table 7.11 indicate that the interaction effect is nonsignificant and LSS Project Residual Risk merely acts as an additive term. The two lines in Figure 7.18 indicates that when the LSS Project Residual Risk is low (= -1) as opposed to being high (= 1), there is higher LSS Project Performance for a given level of LSS Project Execution, which makes sense. However, this additive effect is 0.3 standard deviations, which is not that much, suggesting that residual risk does not dampen LSS Project Performance too much.

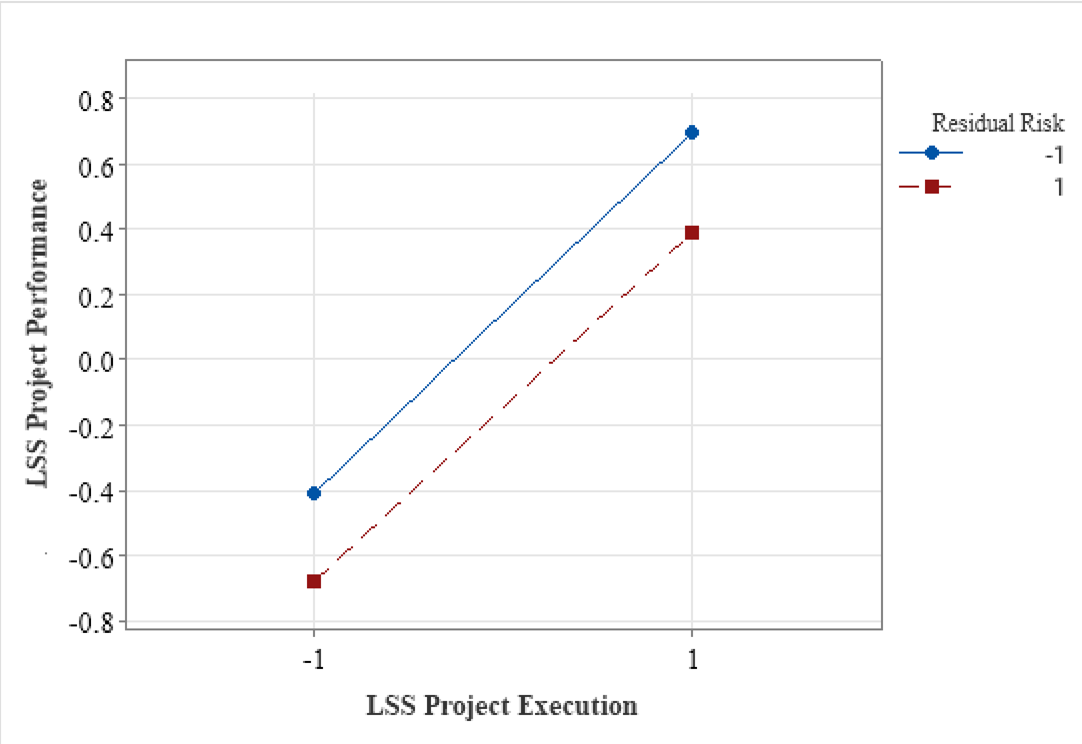


**Figure 7.18 The interaction plot for LSS Project Performance**

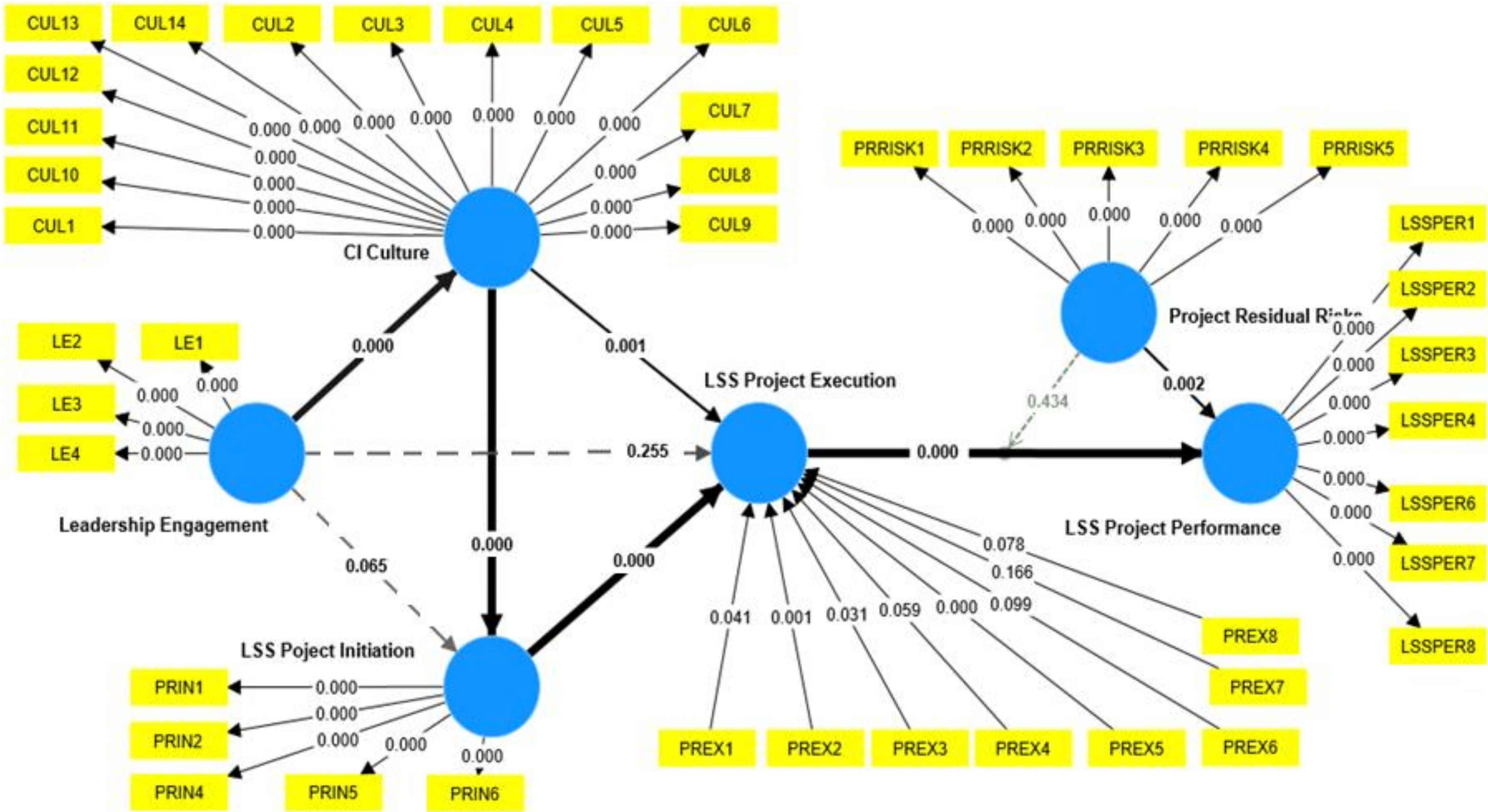


**Figure 7.19 Bootstrap *p*-values of the final PLS-SEM model**

## 7.7 Evaluation of the Overall Goodness-of-fit of the Structural Model

As discussed in Chapter 3, in any SEM approach, the researcher specifies three types of statistical relationships through two assessment criteria: inner model/measurement model assessment (analysing the relationship of construct measures with their assigned construct), outer model/structural model assessment (analysing the hypothesised relationship between the constructs themselves) and the overall goodness-of-fit (a single parameter that examines the goodness-of-fit of all specified statistical relationships to the data). Yet in PLS-SEM there is no well-established global goodness-of-fit measurement that can be used to determine whether the model fits the data in its entirety or not (Hair et al., 2019; Noori, 2015). Thus, in PLS-SEM, the fit of the overall model is determined separately by the measurement model and the structural model. Evaluation of the goodness-of-fit of the measurement model relies on the communalities, CR, and the AVE of constructs, while evaluating the goodness-of-fit of the structural model is based on the coefficient of determinants (R2), predictive relevance (Q2), effect size and significance of the path coefficients and Cohen's f 2 global.

**Table 7.13 Explanatory power of the structural model**

| Endogenous Construct | $R^2$-value | Cohen's $f^2$ Global | $Q^2$ value |
|---|---|---|---|
| LSS Performance (LSSPER) | 0.357 | 0.58 | 0.351 |
| CI Culture (CI CUL) | 0.374 | 0.60 | 0.133 |
| LSS Project Initiation (PRIN) | 0.253 | 0.34 | 0.116 |
| LSS Project Execution (PREX) | 0.520 | 1.08 | 0.161 |

The goodness-of-fit of the measurement model was deemed good as the CR and AVE values of the measurement model (Table 7.7) passed the thresholds easily. As discussed in Chapter 3, in any SEM approach, the researcher specifies three types of statistical relationships through two assessment criteria: inner model/measurement model assessment (analysing the relationship of construct measures with their assigned construct), outer model/structural model assessment (analysing the hypothesised relationship between the constructs themselves) and the overall goodness-of-fit (a single parameter that examines the goodness-of-fit of all specified statistical relationships to the data). Yet in PLS-SEM there is no well-established global goodness-of-fit measurement that can be used to determine whether the model fits the data in its entirety or not (Hair et al., 2019; Noori, 2015). Thus, in PLS-SEM, the fit of the overall model is determined separately by the measurement model and the structural model. Evaluation of the goodness-of-fit of the measurement model relies on the communalities, CR, and the AVE of constructs, while evaluating the goodness-of-fit of the structural model is based on the coefficient of determinants (R2), predictive relevance (Q2), effect size and significance of the path coefficients and Cohen's f 2 global.

Table 7.13 reports the R2, Q2, and Cohen's f 2 global, for the purpose of assessing the goodness-of-fit of the structural model. As the R2 value ranges from 0 to 1, the higher the value, the greater the degree of explanatory power. As a general rule, Cohen (1992) and Myors et al. (2008) suggest that R2 should be considered based on the explanatory power of endogenous constructs as follows: 0.02 (weak), 0.13 (moderate) and 0.25 (large). However, the interpretation of R2 is dependent upon the context in which it is used, including the discipline (Hair et al., 2022). The f 2 and Q2 effect sizes were examined for endogenous constructs that are being predicted/explained by one or more constructs. As mentioned previously, based on Cohen's guidelines (Cohen, 1992, p. 157), an f 2 = 0.02 indicates a small predictor-response effect, f 2 = 0.15 a medium predictor-response effect, and f 2 = 0.35 a large predictor-response effect, in relation to linear regression analysis. The guidelines for Q2 (predictive relevance) are that Q2 = 0.02 is weak, Q2 = 0.15 is moderate, and Q2 = 0.35 is strong (Hair et al., 2022). Based on the information reported in Table 7.13, it appears that the explanatory power of the structural model is large based on R2 and f 2 guidelines of Cohen (1992), but mostly moderate based on the Q2 guidelines of Hair et al. (2022). The conclusion is that the overall model fits to data sufficiently well to interpret the hypothesis test results confidently.

## 7.8 Implications of the Correlations between the Constructs

Before moving to the multigroup analysis to test H9, the correlation matrix of the constructs is shown in Table 7.14. The correlations between the constructs, the mean and standard deviations of the constructs, and the sample size (*n* = 296) are sufficient for an analyst to conduct an independent analysis on the researcher's theory (or an alternative theory if the analyst wants to) using a suitable data analysis technique such as path analysis based on CBSEM. While CBSEM results and the researcher's results (e.g., path coefficients) will not match perfectly as the two methods use different parameter optimisation methods, the results should come close. In any case reporting the researcher's data in concise fashion as a correlation matrix is deemed good practice as the researcher's data can be used by other academics for different purposes, or simply to verify the researcher's results. The mean scores of the constructs will be used in the discussion (section 7.10) and conclusion (Chapter 8), which is another reason why the correlation matrix was reported.

The correlation matrix has been prepared based on the unstandardised scored scores (296 cases) of the constructs generated by the PLS-SEM software. It must be noted that in PLS-SEM, the construct score is taken as the weighted average of its indicator scores (the weights are estimated as part of the analysis).

**Table 7.14 Correlations between the constructs**

| Construct Abbreviation | CICUL | LE | LSSPER | PREX | PRIN | PRRISK |
|---|---|---|---|---|---|---|
| CICUL | | | | | | |
| LE | 0.612 | | | | | |
| LSSPER | 0.368 | 0.302 | | | | |
| PREX | 0.521 | 0.392 | 0.584 | | | |
| PRIN | 0.496 | 0.392 | 0.471 | 0.687 | | |
| PRRISK | 0.264 | 0.088 | 0.273 | 0.240 | 0.153 | |
| Mean | 5.595 | 5.704 | 5.982 | 5.787 | 5.993 | 4.364 |
| Standard Deviation | 0.889 | 1.116 | 0.706 | 0.690 | 0.710 | 1.226 |

**Note:** For the correlation between LE and PRRISK, the p value is 0.142; for the correlation between PRIN and PRRISK, the p value is 0.008. For the remaining pairs of correlations, $p < 0.001$.

One important observation is that correlations between the constructs are not excessive, implying no conceptual overlap (something that was more definitively established by the discriminant validity test) and the mean score of Project Residual Risks (PRRISK) is much lower (= 4.364 implying the midpoint in the 1-7 Likert scale) than the mean scores of the remaining constructs. The mean values of PRRISK for manufacturing and nonmanufacturing sectors were 4.236 and 4.509 respectively, but at 0.05 significance level, the difference was found to be nonsignificant ($p = 0.074$), based on the two-tailed test. Thus, an interpretation of the apparently different mean scores of PRRISK is not required (the difference is considered to be reflecting the sampling error).

Another important observation is that PRRISK is not correlated with any other construct in a practically significant way. This is expected because the model treats PRRISK as an exogenous construct that has only two theoretical relationships with LSSPER: the main effect and the two-way interaction related to H8. The strongest correlation is between PRRISK and LSSPER, which is 0.273 and there is a theoretical relationship between the two constructs to represent H8 (e.g., H8a required the researcher to examine the main effect of PRRISK on LSSPER).

## 7.9 Model Fit to Manufacturing vs. Nonmanufacturing: Testing H9

### 7.9.1 Multigroup analysis

Multigroup analysis (MGA) is a technique that is used to examine whether model parameters across two groups are significantly different (Hair Jr et al., 2017; Henseler et al., 2016; Matthews, 2017). In this section, MGA is conducted in relation to PLS-SEM in respect of the theoretical model that was previously tested for full data (i.e., data corresponding to 296 manufacturing and nonmanufacturing organisations). To answer RQ3, it becomes necessary to demonstrate that there is no statistically significant difference in path coefficients between the nonmanufacturing group and the manufacturing group because the corresponding hypothesis H9 expects a null (no difference) result to support the statement: the LSS model fits to nonmanufacturing firms as well as it would to manufacturing firms. To do this in an MGA setting, it becomes necessary to show that there is measurement invariance across the two groups for the theoretical constructs. If measurement invariance (more precisely the configurational invariance and compositional invariance) cannot be supported, MGA would be aborted as the conclusions could sometimes become misleading (Henseler et al., 2016; Matthews, 2017). MGA is outlined by Matthews (2017) as a step-by-step process, and Chapter 4 outlines each step-in detail.

***Data Preparation for MGA***

The very first step of the data preparation process is to separate manufacturing and nonmanufacturing sector data. The SmartPLS group has been identified as a set of codes (manufacturing cases were set as group A and nonmanufacturing cases were set as group B). The next crucial factor to consider in step 1 is to investigate the sample size to determine whether the sample sizes of each group is large enough to meet statistical power guidelines of Cohen (1992). For data of this research, the sample size for the manufacturing group is 158 and for the nonmanufacturing group it is 138. To exceed the minimum $R^2$ of 0.10 (effect size = 0.11) at a 5% significance level, both the manufacturing and nonmanufacturing groups would need to exceed 124 samples (Cohen, 1992; Hair Jr *et al.*, 2017) as shown in Table 7.15. Accordingly, both groups meet the requirements for statistical power, based on Cohen's guidelines used by Hair Jr *et al*. (2017).

**Table 7.15 Sample size of subpopulation**

| **Sub population** | ***Sample size*** | **Minimum sample size ($R^2$ =0.1 at 5% significance level)** |
|---|---|---|
| Manufacturing | 158 | 102 |
| Nonmanufacturing | 138 | 102 |

***Test for Invariance - MICOM***

As mentioned in Chapter 4 section 4.7.2, three different layers of invariance were to be examined: configural invariance, compositional invariance, and scaler invariance. Configural invariance is a method of examining the structural equivalence of constructs. It is essential to fulfil the following criteria to ensure configural invariance: (a) same indicators under each measurement model, (b) same data treatment, and (c) same algorithm settings or optimisation criteria for the application of each measurement model. Since RQ3 prompts the researcher to examine the final model fit over the two sectors (manufacturing and nonmanufacturing) both data sets used the same model thus meeting the configural invariance requirement. Measurement Invariance by Means of Composite Models (MICOM) is a procedure that is designed to test compositional invariance in PLS-SEM by using a composite model. Measurement invariance was confirmed because the permutation *p* values returned nonsignificant *p* values shown in Table 7.16.

**Table 7.16 Results on compositional invariance and scalar invariance of manufacturing vs. nonmanufacturing data**

| Construct | Compositional Invariance | | Mean Invariance | | Equal variance established |
|---|---|---|---|---|---|
| | Permutation p-value | **Invariance established** | Permutation p-value | **Invariance established** | |
| CI Culture | 0.359 | Yes | 0.106 | Yes | Yes |
| LSS Project Initiation | 0.817 | Yes | 0.002 | No | Yes |
| LSS Project Execution | 0.393 | Yes | 0.024 | No | Yes |
| LSS Project Performance | 0.628 | Yes | 0.110 | Yes | Yes |
| Leadership Engagement | 0.939 | Yes | 0.524 | Yes | Yes |
| Project Residual Risks | 0.875 | Yes | 0.074 | Yes | Yes |

According to the mean invariances results and difference of variances in As mentioned in Chapter 4 section 4.7.2, three different layers of invariance were to be examined: configural invariance, compositional invariance, and scaler invariance. Configural invariance is a method of examining the structural equivalence of constructs. It is essential to fulfil the following criteria to ensure configural invariance: (a) same indicators under each measurement model, (b) same data treatment, and (c) same algorithm settings or optimisation criteria for the application of each measurement model. Since RQ3 prompts the researcher to examine the final model fit over the two sectors (manufacturing and nonmanufacturing) both data sets used the same model thus meeting the configural invariance requirement. Measurement Invariance by Means of Composite Models (MICOM) is a procedure that is designed to test compositional invariance in PLS-SEM by using a composite model. Measurement invariance was confirmed because the permutation p values returned nonsignificant p values shown in Table 7.16, it is evident that the two groups do not satisfy the scalar invariance requirement (same mean and variance) very well (meets the same variance requirement but not the same mean requirement for two constructs). Accordingly, the researcher claimed partial measurement invariance and proceeded with MGA to compare the standardised coefficients of the structural model across groups.

***PLS-MGA with Partial Invariance***

The concept of partially invariant measurements provides flexibility for some parameters (loadings, intercepts, residuals), whereas fully invariant measurements require all parameters to be the same, regardless of the calculation (Carranza *et al.*, 2020; Hair *et al.*, 2022; Matthews, 2017). Table 7.17 shows the results—more specifically the differences in the values of the path coefficients—of PLS-MGA and the establishment of invariances through permutation method. Notable findings across the two groups include: a similar CI Culture → LSS Project Initiation relationship (low apparent difference in the path coefficients); a similar Leadership Engagement → CI Culture relationship; and a similar Leadership Engagement → LSS Project Execution relationship. LSS Project Execution → LSS Project Performance relationship unveils a noteworthy disparity of -0.217 (leaning towards nonmanufacturing), substantiated by a statistically significant *p-value* of 0.032.

**Table 7.17 Difference in path coefficients and significance**

| Path | Invariance Established (Permutations) | Difference (Manufacturing - Nonmanufacturing) | PLS MGA (p-value) |
|---|---|---|---|
| CI Culture → LSS Project Initiation | Yes | -0.091 | 0.498 |
| CI Culture → LSS Project Execution | No | 0.158 | 0.382 |
| LSS Project Initiation → LSS Project Execution | Yes | -0.116 | 0.372 |
| LSS Project Execution → LSS Project Performance | Yes | -0.217 | 0.032 |
| Leadership Engagement → CI Culture | Yes | 0.073 | 0.642 |
| Leadership Engagement → LSS Project Initiation | No | 0.278 | 0.126 |
| Leadership Engagement → LSS Project Execution | Yes | -0.09 | 0.622 |
| Project Residual Risks → LSS Project Performance | Yes | -0.011 | 0.914 |
| Project Residual Risks x LSS Project Execution → LSS Project Performance | Yes | 0.085 | 0.458 |

Although the LSS Project Execution → LSS Project Performance causal path appears to be stronger in nonmanufacturing than in manufacturing on account of the statistically significant difference in the path coefficients, this finding was not considered as a finding convincing enough to refute H9. One reason for this is that MGA was done under the condition of partial invariance. Another reason is that based on the problem-solving approach being used (section 7.3.2) and the methodology and tool being used (section 7.3.5) the manufacturing and nonmanufacturing sectors showed no difference (based on the Chi-squared test). The conclusion is there that H9 is supported by the data, but more research needs to be done to support or refute H9 more convincingly.

## 7.10 Discussion

The discussion on the hypothesis test results is covered in this section.

### 7.10.1 Discussion of the Results from a Practical Perspective

***Causation of LSS Project Initiation***

The predictors of LSS Project Initiation are Leadership Engagement and CI Culture. This means the joint effect of Leadership Engagement and CI Culture leads to the LSS Project Initiation. Results suggest that CI culture has a greater effect ($\beta = 0.413$, $f^2 = 0.14$, $p < 0.001$) on LSS Project Initiation than Leadership Engagement directly ($\beta = 0.142$, $f^2 = 0.08$, $p = 0.065$). In fact, at 0.05 significance level data just fails to support the direct effect of Leadership Engagement on LSS Project Initiation. However, the results clearly show that Leadership has an indirect effect (= 0.253, $p < 0.001$) through the Leadership Engagement→CI Culture→ LSS Project Initiation mediation relationship. The results make practical sense because the role of leadership is not to micromanage project initiations but to create an environment and inspire the followers to do their job well (Antony et al., 2018; Knapp, 2015; Zu et al., 2010).

***Causation of CI Culture***

CI Culture is caused by Leadership Engagement in LSS projects (***H2***). At organisational level, the culture is caused by the Leadership (Cameron & Quinn, 2011b; Laureani & Antony, 2019; Schein, 2010). The results show that the impact of Leadership Engagement on CI Culture is strong ($\beta = 0.612$, $f^2 = 0.60$, $p < 0.001$), and high leveraging (an increase in 10% in Leadership Engagement increases CI Culture by 6.12%).

***Causation of LSS Project Execution***

The predictors of LSS Project Execution are Leadership Engagement, CI Culture, and LSS Project Initiation. Successful execution of an LSS project can be attributed to direct Leadership Engagement ($\beta = 0.046$, $f^2 = 0.00$, $p = 0.225$), CI Culture ($\beta = 0.246$, $f^2 = 0.07$, $p = 0.001$), and LSS Project Initiation ($\beta = 0.537$, $f^2 = 0.44$, $p < 0.001$). However, the data suggests that Leadership Engagement has no direct effect on LSS Project Execution (***H3***). This is not surprising because leaders are responsible for driving the system to achieve expected outcomes and its effects on processes are felt through system constructs (Rangsungnoen, 2022; Wilson & Collier, 2000). Among the two significant causal antecedents, LSS Project Initiation influences LSS Project Execution ($f^2$ = 0.44) much more than CI Culture ($f^2$ = 0.07). Culture is just a catalyst for facilitating execution of an LSS project, once initiated. If the initiation is poor, the execution would be poor. Hence, a strong direct relationship between initiation and execution makes sense from a practical perspective. Finally, given that Leadership Engagement is an indirect driver, the question, “If Leadership Engagement has no direct effect on LSS Project Execution, to what extent does Leadership Engagement indirectly affect it?" should be asked. According to the results shown in the second step, attention is focused on indirect effects, mainly to make sense out of unsupported hypotheses on direct effects (shown as dashed lines in Figure 7.19). For example, although data failed to support H1 at 0.05 significance level ($p = 0.065$), LE could still have a significant effect on PRIN indirectly through the mediator CI Culture (see Figure 7.17 to visualise the mediating paths). Table 7.12 lists all the indirect relations, their effects, and significance (p-values). The results in Table 7.12 clearly indicate that all indirect paths are significant. Table 7.12 (total indirect effects) the answer is 0.36 ($p < 0.001$). This is a significant/large effect based on Cohen’s effect size classification (Cohen, 1992).

### *Causation of LSS Project Performance*

LSS Project Performance is a result of LSS Project Execution (***H7***), but the LSS Project Execution→LSS Project Performance relationship is moderated by Project Residual Risk, according to the model. The results show that while LSS Project Execution has a strong Effect on LSS Performance ($\beta = 0.543$, f2 = 0.41, $p < 0.001$), this relationship is not moderated by Project Residual Risk. As shown in Table 7.11, the interaction moderation term PRRISK*PREX is not significant ($p = 0.434$). However, the results show that while Project Residual Risk does not act as a moderator, it still negatively affects LSS Project Performance through its main effect. A (as shown in Table 7.11), PRRISK□LSSPER relationship returns $\beta = -0.144$, f2 = 0.03, $p = 0.001$. Additionally, based on Cohen’s guidelines stated earlier (Cohen, 1992), the size of this effect is small (f2 is only 0.03). The practical implication of this low f 2 may mean that in LSS projects, quality risk management (risk controls) receives significant attention to the point that residual risks hardly make any significant impact on performance. There is also evidence that Project Residual Risks have been low in LSS projects based on the mean scores (section 7.8), which seems to suggest that risk considerations have been considered by the project teams at the project initiation stage. As Leadership Engagement is the driver and there is no direct link between Leadership Engagement and LSS Project Performance, the question arises as to what extent Leadership Engagement affects LSS Project Performance via the system/mediators. As shown in the second step, attention is focused on indirect effects, mainly to make sense out of unsupported hypotheses on direct effects (shown as dashed lines in Figure 7.19). For example, although data failed to support H1 at 0.05 significance level ($p = 0.065$), LE could still have a significant effect on PRIN indirectly through the mediator CI Culture (see Figure 7.17 to visualise the mediating paths). Table 7.12 lists all the indirect relations, their effects, and significance (p-values). The results in Table 7.12 clearly indicate that all indirect paths are significant. Table 7.12 on total indirect effects, the effect of Leadership Engagement on LSS Project Performance is 0.216 ($p < 0.001$), which is a notable (medium) effect, based on Cohen's effect size classification (Cohen, 1992).

### 7.10.2 Discussion of the Results from a Theoretical Perspective

The research adds to the current body of knowledge in extending the theoretical underpinnings of SS and LSS in following ways.

The study of Schroeder *et al.* (2008) resulted in a model which proposed that Leadership Engagement results in strategic project selection and creation of improvement specialists to apply a structured problem-solving method to achieve SS outcomes. The theory advanced by the researcher supports the said proposition by way of testing it in a suitably adapted form to an LSS project environment. While the cause and the effect of the researcher's model (Figure 7.17) are the same as those in Schroeder et al.'s paper, the researcher expands the structured problem-solving notion advanced by Schroeder et al. through LSS Project Initiation and LSS Project Execution. LSS Project Initiation also considers the strategic project selection notion advanced by Schroeder *et al.* (2008). Similarly, this research replaces the "improvement specialists" notion advanced by Schroeder et al. by CI Culture to reflect the evolution of SS 15-20 years ago into LSS as it is being practised now.

The theory advanced by the researcher also stands analogous to the theory advanced by Zu et al. (2008). However, the researcher does not conceptualise two parallel infrastructures — the

TQM Infrastructure and SS Infrastructure — as mediators in the Top Management Support→Quality Performance relationship. In contemporary LSS literature, the parallel infrastructure conceptualisations advanced by Zu et al. (2008) and Schroeder et al. (2008) are hardly mentioned, and the case study of the researcher also suggested nonexistence of two parallel infrastructures. This could be because of infusion of Lean into very role-driven SS methodology and the natural metamorphosis of SS into LSS.

Sin et al. (2015) posited that SS project success is attributable to organisational knowledge creation (both tacit and explicit) due to socialisation, externalisation, combination, and internalisation. They used *learning* as the theoretical lens, whereas the project management lens used by the researcher has resulted in her model aligning (not intentionally) to TQM and the performance excellence notion of leadership driving the system to achieve results (Rangsungnoen, 2022; Wilson & Collier, 2000). Within this system, knowledge assets still play a significant role. While the researcher does not use knowledge as a construct, knowledge is embedded in the CI Culture, LSS Project Initiation, and LSS Project Execution. Similarly, Arumugam et al. (2016) posited that SS project performance is caused by challenging goal setting (the causal link being mediated by knowledge and moderated by method), but they used goal theory as their theoretical lens. Again, goal setting is embedded in this study in LSS Project Initiation. It is argued that the theory advanced by the researcher also aligns with current thinking on ISO 9001 and ISO 9004 quality management system standards, which are built upon risk-based thinking, continual improvement, and the process approach (ISO, 2015). In this research, risk-based thinking is primarily covered in LSS Project Initiation, continual improvement is covered by CI Culture, and the process approach is covered in both LSS Project Initiation and LSS Project Execution. Theoretical frameworks on SS and LSS used in other studies can also be compared with the theory advanced by the researcher, but the researcher's study aligns mostly with the studies by Schroeder et al. (2008) and Zu et al. (2008).

The MGA suggested that LSS fits to nonmanufacturing firms as well as it would to manufacturing, based on the researcher's theory (the researcher has argued at length that her theoretical model has been correctly specified and the measurement and structural models pass the tests on validity, reliability, and statistical conclusions). Many leading SS/LSS scholars in the field (e.g. Antony et al., 2007; Snee, 2007) as well as the so-called consultants have argued that LSS fits nonmanufacturing as well as it would for manufacturing using case studies and conceptual arguments. The researcher has been able corroborate this claim scientifically. In addition, Schmenner and Swink (1998), the inventors—the theory of swift and even flow—have argued that Lean and SS are methodologies that facilitate swift and even flow and that the concept of swift and even flow (hence Lean and SS by default) is applicable to manufacturing and nonmanufacturing equally well. Theory of swift and even flow is a theory on productivity that emphasises materials or information moving through a process swiftly (to reduce the throughput time) with minimal variability for productivity gains (Schmenner & Swink, 1998). Thus, it is concluded that H9 is an important hypothesis and the empirical evidence in support of H9 adds to the wider body of knowledge on operations management.

## 7.11 Chapter Summary and Conclusion

Descriptive statistics presented in section 7.2 and 7.3 not only provided a range of useful information about the respondents, their organisation, methods and LSS tools being used, but these also suggested that a reasonably representative sample is available to make the data analysis, particularly hypothesis testing meaningful.

PLS-SEM path analysis results in relation to the measurement model (section 7.5) showed that the six constructs of the research are empirically valid, based on the operationalisations that the researcher used (in lay language, the 45 questionnaire statements on different facets of the six constructs). This is an important finding because RQ1 (What are the determinants that predict and explain how quality performance is achieved by implementing LSS?) can never be fully answered unless a scientist shows that the hypothesised determinants exist to explain how quality performance (labelled as LSS Project Performance in this study) is caused. Thus, demonstration of construct validity confirmed the determinants: Leadership Engagement, CI Culture, LSS Project Initiation, LSS Project Execution, and Project Residual Risks. The reader should interpret labels LSS Project Initiation and LSS Project Execution as strong LSS Project Initiation and strong LSS Project Execution respectively because any project needs an initiation and an execution. PLS-SEM path analysis results in relation to the measurement model also showed that project residual risks are reflected by only five facets as shown in in Table 7.18.

**Table 7.18 Five facets of project-related residual risks**

| Indicator | Facets | Question in questionnaire |
|---|---|---|
| PRRISK1 | Difficulty in anticipating technological requirements | The project team were unable to anticipate technology needs. |
| PRRISK2 | Interdependence of project tasks | Due to the interdependence of project tasks, it was difficult for the team to assess the project needs. |
| PRRISK3 | Difficulties in obtaining approvals within a hierarchical structure: | It was difficult for the project team to obtain approvals due to the organisation's hierarchical structure. |
| PRRISK4 | Uncertainties in regulatory changes and stakeholder expectations | The project team found it difficult to assess the expectations of external stakeholders due to regulatory changes. |
| PRRISK5 | Uncertainties in the external environment | Due to uncertainties in the external environment, the team was unable to predict business, social and environmental impacts (e.g., politics, economics, the law, and natural conditions). |

PLS-SEM path analysis results in relation to the structural model (section 7.6) showed empirical support for majority of the hypothesised theoretical relationships between the constructs. The main departure was in the way Leadership Engagement affects Project Initiation and Project Execution. Although it was hypothesised that Leadership Engagement has a direct positive effect on Project Initiation (H1), empirical results suggested that Leadership Engagement has only an indirect effect on Project Initiation (the direct effect was not supported at 0.05 significance level as the p value was 0.065, which some scholars may consider a weak support as opposed to no support). Similarly, although it was hypothesised that Leadership Engagement has a direct positive effect on Project Execution (H3), empirical results suggested that Leadership Engagement has only an indirect effect on Project Execution. What these and other hypothesis mean was discussed (section 7.10). The hypotheses that were not empirically supported by the data suggests that the researcher's theory can be reshaped (modification of the causal predictive mechanism) to provide more useful practical and theoretical insights on LSS project success. MGA (section 7.9) supported H9 which posits that "the LSS model fits to nonmanufacturing as well as it would to manufacturing at a theoretical level". The next chapter concludes the study by showing how the objectives were achieved, what contributions the study made to academia and the practice of LSS, limitations of the study, and suggestions for further research.

# CHAPTER 8
# CONCLUSION

## 8.1 Introduction

This chapter concludes the thesis. The thesis is titled "Theorising and testing the underpinnings of LSS Success" because the main focus of the study is to develop and test a theory to explain how success is caused by implementing LSS projects. The main deliverable of the research is therefore the researcher's theoretical model. The project lens employed by the researcher allows her to compress her theoretical model to represent the common-sense notion that "a project needs to be initiated and executed well to achieve success". By utilising academically valuable conventions such as mediation, moderation, and boundary conditions to build her theory, and having tested it empirically, the researcher is now able to demonstrate the mechanism that causes success or failure of a LSS project.

The research design of the study (details in the methodology chapter) followed an exploratory sequential mixed-method design, in which the qualitative study (a case study involving 16 participants from five countries) informed the quantitative study (a survey research based on data collected from 296 LSS practitioners around the world). The qualitative study enabled the researcher to understand the context of LSS[30] and facilitation of the operationalisation of the theoretical concepts (some concepts were not well defined in the literature, thus needing to understand how these concepts manifested in practice) for the purpose of quantitative data collection. The quantitative study enabled the researcher to test her theory empirically, for which the PLS-SEM technique was used as the major data analytic technique.

Three research questions were posed to bridge the knowledge gap identified via the literature review. These questions served as a vehicle to achieve the five research objectives (Figure 8.1). Therefore, this chapter begins with an overview of the overall findings of this research against each objective (section 8.2). Thereafter, the researcher moves on to highlight the contributions of the study to academia (section 8.3) and contributions to practise of LSS (section 8.4), limitations of the study and finally, suggestions for further research.

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[30] Under context, the aspects covered included how users define LSS, how users incorporate Lean principles and the SS/DMAIC methodology, project reporting structures, training approaches, and understanding how project-related contingencies are handled/considered in LSS projects.

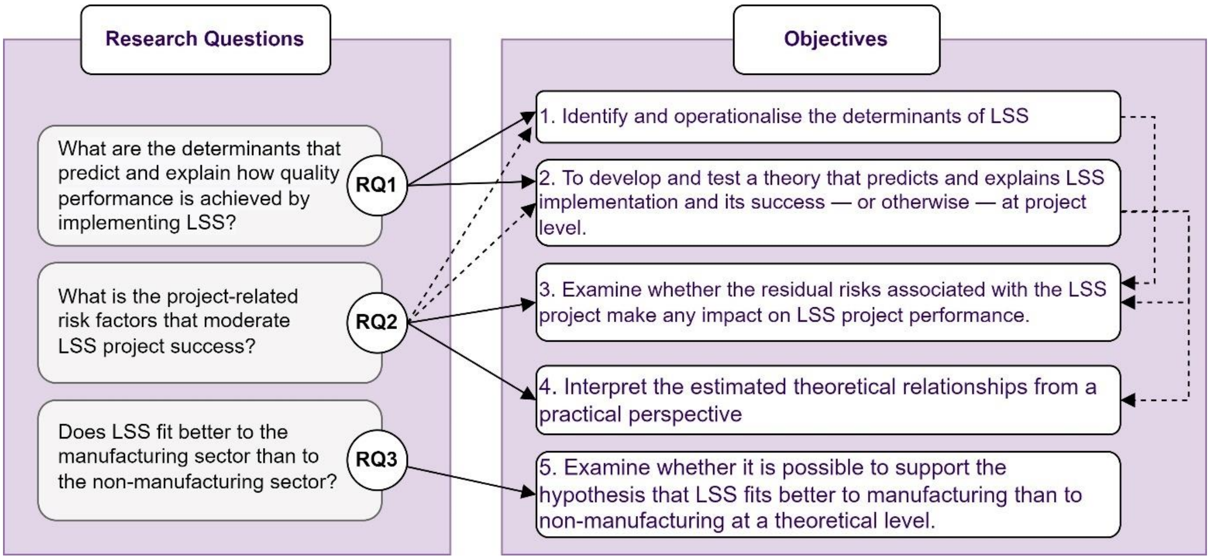



**Figure 8.1 Mapping research objectives to research questions**

## 8.2 Empirical Findings Against the Research Objectives

### 8.2.1 Achieving Research Objective 1: Identifying and operationalising the determinants of LSS.

The first objective of this study was to identify and operationalise the determinants of LSS within the context of project-level quality performance. As far as this research is concerned, the determinants of LSS or the constructs of LSS mean the same thing. As mentioned in the introduction chapter, the term quality performance is used in this research to mean not just meeting or exceeding quality of conformance, but also things such as waste reduction, cost savings etc. that are important to the customers. The reader is advised to refer to the eight measures being included in the survey questionnaire to capture the concept "LSS Project Performance" (Appendix D).

To achieve objective 1, several sequential steps were followed as shown in Figure 8.2. A three-pronged approach involving an extensive literature review, computer generated literature synthesis through ML, and industrial scoping via case research was adopted to finalise the constructs that explain how quality performance is achieved in LSS projects. Table 8.1 shows very briefly how the three approaches harmonise as a consolidated approach.

**Table 8.1 Showing the harmony of the three approaches used to achieve objective 1**

| Approach | Why Each Approach was Needed |
|---|---|
| Step 1: Extensive literature review | To understand how Lean, SS, and LSS have been conceptualised as theoretical frameworks. |
| Step 2; Computer generated literature synthesis though ML | To let artificial intelligence to resolve a large number of CSFs published in many peer-reviewed journal articles to a manageable number of concepts |
| Step 3: Industrial scoping via case research | While merging the findings of step 1 and step 2 resulted in identifying the theoretical concepts (determinants of LSS), minor tweaking was necessary to accurately represent the outcome concept quality performance (rationalised as LSS Project Performance); equally importantly, industrial scoping was needed to operationalise the concepts reliably to represent these concepts as constructs. |

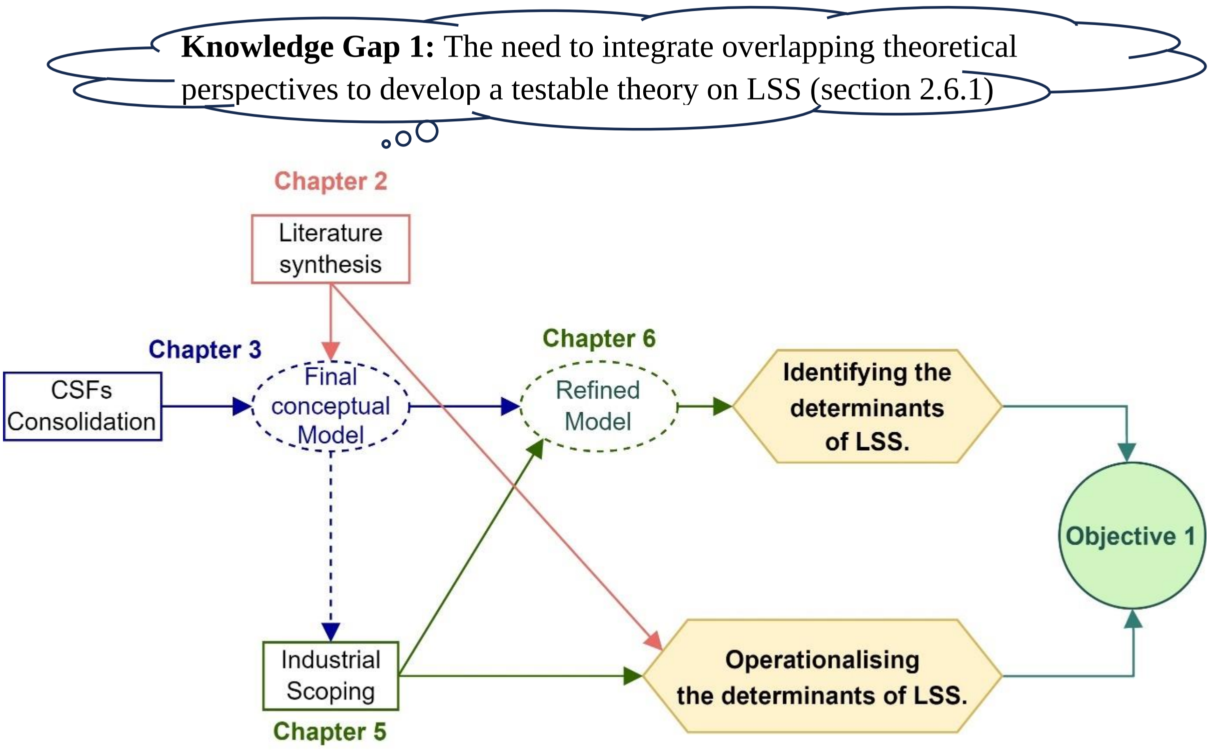



**Figure 8.2 Achieving objective 1: identifying and operationalising LSS determinants**

The determinants of LSS were found to be Leadership Engagement, CI Culture, Project Initiation, Project Execution, Project Residual Risks and LSS Project Performance (the latter being the outcome that is explained). Table 3.8 in Chapter 3 provides a brief description of the determinants. The reader will note that Table 3.8 describes three LSS outcomes: Quality Performance (in a narrower sense), Customer Satisfaction, and Business Performance. It was these three outcomes that were rationalised as a single concept, viz LSS Project Performance. Without a loss of generality, LSS Project Performance can be interpreted as quality performance in a broader sense, in relation to an LSS project, which is the unit of analysis of this study. Figure 8.3 shows how the literature and fieldwork (industrial scoping) were used side by side to understand the determinants of LSS and well as their outcome (i.e., LSS Project Performance).

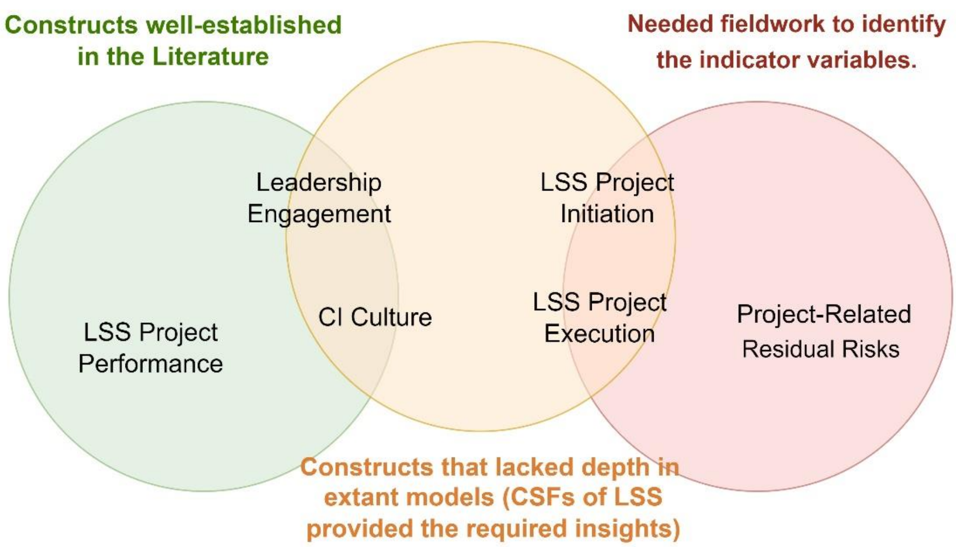



**Figure 8.3 Assessing LSS determinants**

The operational definitions of the determinants of LSS (the second part of objective 1) as well as those of LSS Project Performance are shown via statements in Appendix D (See Part 2, titled "Measurement Related Survey Items"). As mentioned elsewhere, the operational definitions of a construct define how the construct manifests in the real world (for traditional constructs) or how the construct is formed (for formative constructs) to interpret its meaning. In this study, the only formative construct happened to be LSS Project Execution. Without operationalising the constructs, it is not possible to develop the indicators of the constructs to collect quantitative data to test the hypotheses.

### 8.2.2 Achieving Objective 2: To develop and test a theory that predicts and explains LSS implementation and its success — or otherwise — at project level.

Some of the work required to achieve the second objective was subsumed in the work covered under objective 1. The theory development aspect related to objective 2 involved hypothesising the relationships between the concepts as well as operationalising the concepts. The three approaches followed to achieve objective 1 (Table 8.1) also resulted in developing the hypothesised relationship between the constructs — first, by developing the conceptual model and then, refining it via case studies. The reader may want to go back to Figure 6.1 to recollect how the hypothesised theoretical relationships collectively represent the researcher's theoretical model. There are eight hypotheses in the researcher's theory and again, the reader may want to go back to Table 6.1 to understand what the eight hypotheses posit. The theory development aspect related to objective 2 related to testing the eight hypotheses using quantitative data collected (296 valid responses), thanks to the operational definitions of the constructs (objective 1). A summary of the process used to achieve objective 2 is shown in Figure 8.4.

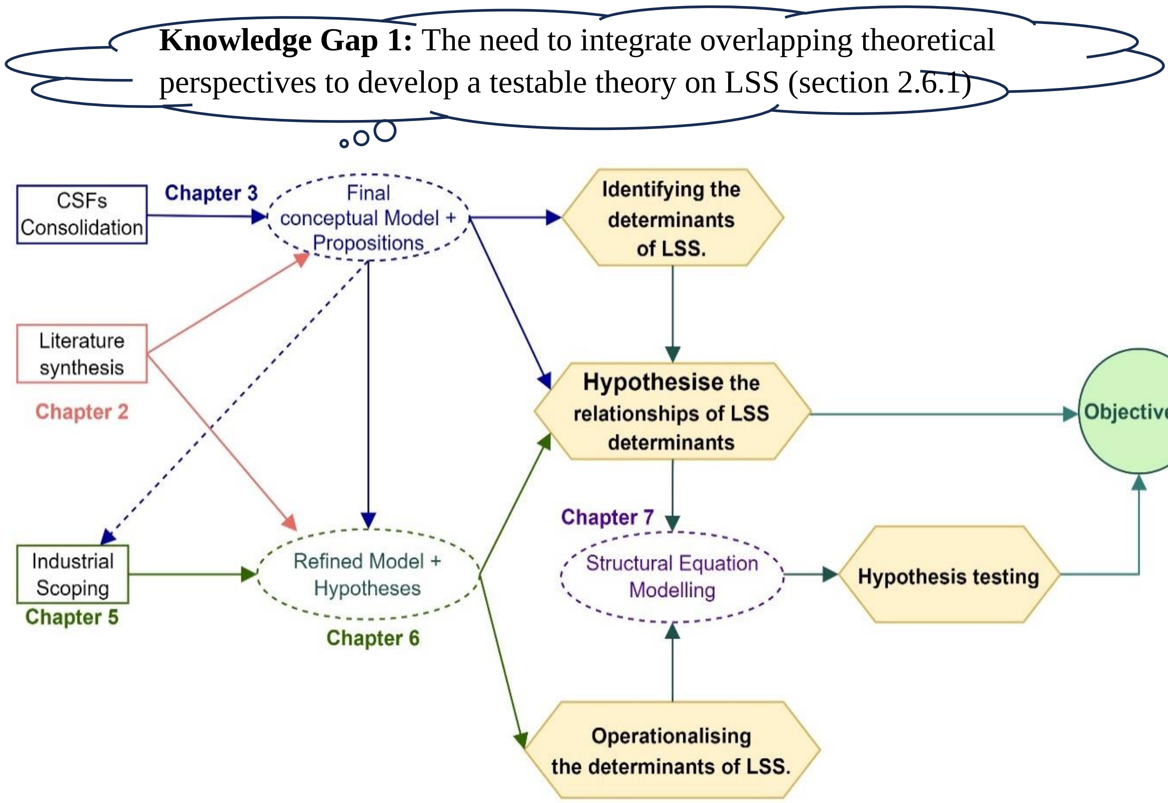



**Figure 8.4 Achieving objective 2: formulating and testing hypothetical relationships between the determinants of LSS.**

The researcher’s theory can be condensed to a single overall hypothesis or a statement that collectively represent the eight hypotheses. The overall hypothesis is that “Leadership Engagement drives LSS Project Execution through the mediating effects of CI Culture and LSS Project Initiation to cause LSS Project Performance, and that the LSS Project Execution → LSS Project Performance path is moderated by Project Residual Risks (See Figure 6.1).

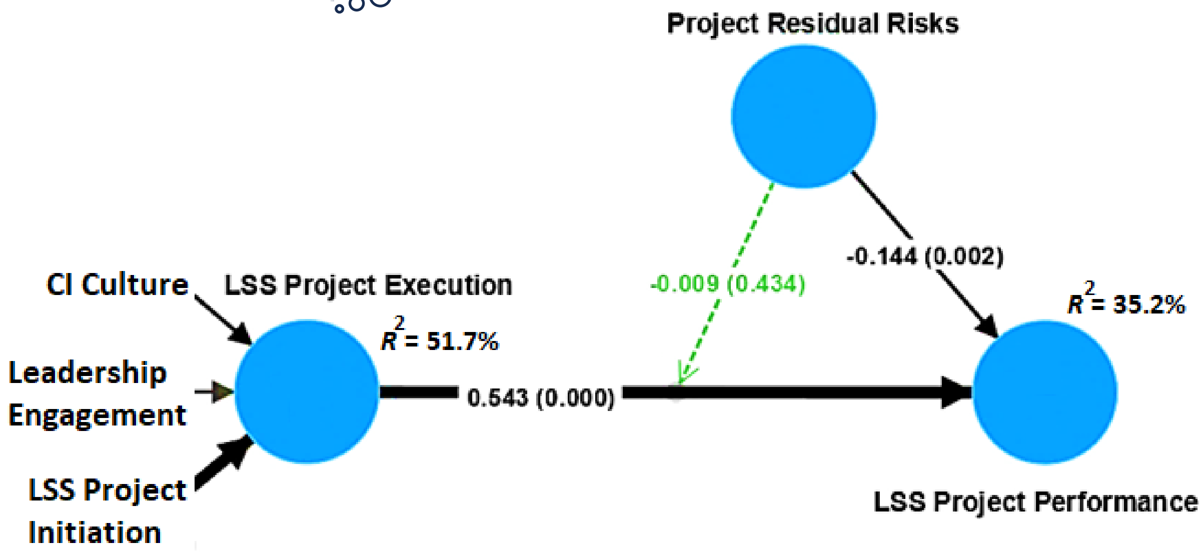
The study found that Leadership Engagement has no direct effect on LSS Project Initiation or LSS Project Execution and that the leadership’s effect on those two dimensions is felt through the mediation effect of CI Culture. It was argued that this finding is consistent with most leadership situations where the role of the leader is not micromanaging projects but to create an environment (in this study, the CI Culture) for successful project initiation and execution. It was also argued that the model posited and tested in this study stands analogous to current understanding of quality and performance excellence literature, which supports the notion that the role of the leadership is to drive the system to achieve results. The model was compared with studies that explained LSS/SS phenomenon using different theoretical lenses; this is to position the theoretical contribution of the study as an extension to the current body of knowledge (more about this in section 8.3). The empirical findings also implied that risk management is taken care of in LSS projects, in the sense, the risk that remained (Project Residual Risks) had a small effect on LSS Project Performance (Cohen’s $f^2 = 0.03$), from a practical perspective.

### 8.2.3 Achieving Objective 3: Examine whether the residual risks associated with the LSS project make any impact on LSS Project Performance.

The third objective of this research, which still pertains to knowledge gap 1, is to investigate the influence of residual risks on LSS Project performance to identify the extent to which these risks may have an impact on performance. As mentioned elsewhere, residual risk is the risk that persists even after significant efforts have been made to mitigate risk. Thus, residual risks can also be termed as inherent risks. Several factors contribute to inherent risks of any project, including unpredictable technological changes, interdependent tasks, hierarchical approval processes, and fluctuating external conditions, which are all beyond the control of a firm.

The investigation of the influence of Project Residual Risks on the LSS Project performance reduces to examining the hypothesis test results of the eighth hypothesis (H8) which pertains to the moderation effect of Project Residual Risks on the LSS Project Execution → LSS Project Performance causal relationship. Figure 8.4 shows the relevant hypothesis test results.

**Knowledge Gap 1:** The need to integrate overlapping theoretical perspectives to develop a testable theory on LSS (section 2.6.1)




Notes: Figures within parentheses are the p values of the estimated path coefficients
The thickness of each path shows its relative strength

**Figure 8.5 Achieving objective 3: relevant path analysis test results.**

The test results related to H8 (Figure 8.5) showed that Project Residual Risks do not moderate the LSS Project Execution → LSS Project Performance causal path ($p$ = 0.434), thus failing to support H8. This literally means that whatever the Project Residual Risks are (a relatively low residual risk project vs relatively high residual risk project), for the same level of LSS Project Execution, one would expect the same performance improvement (the reader may want to examine the interaction plot shown in Figure 7.18). However, the test result showed that Project Residual Risks act as a main effect (in the language of statistical modelling) to attenuate performance (path coefficient = -0.144, $p$ = 0.002). This means that one would expect lower performance in a high residual risk project than a lower residual risk for the same level of LSS Project Execution. However, as mentioned earlier, Project Residual Risks have only a small effect on LSS Project Performance (Cohen's $f^2$ = 0.03).

The above finding (the attenuation effect) carries implications for LSS practice. It suggests that while residual risks are a permanent fixture in project management, it still pays to minimise the impact of residual risks by lowering residual risks. However, the low effect of Cohen's $f^2$ = 0.03 suggests that if the practitioners are unable to reduce residual risks economically, that would not be overly detrimental. The mean score of Project Residual Risks (in the 1-7 Likert scale) was found to be only 4.36 (for manufacturing 4.24 and for nonmanufacturing 4.51) which is a much lower mean score compared to the mean scores of remaining constructs of the model. This means that practitioners have tried to lower residual risks in the planning and implementation stages (especially the former). This a good thing because in standardised units, the reduction of LSS Project Performance due to LSS Project Residual Risks is 0.144*LSS Project Residual Risks.

### 8.2.4 Achieving Objective 4: Interpret the estimated theoretical relationships from a practical perspective.

The above aspect was covered in detail in the previous chapter (section 7.9.1); a summary is provided below to demonstrate that objective 4 was also achieved.

***The Interplay Between Leadership Engagement, CI Culture, and LSS Project Initiation***

The path analysis results suggested that Leadership Engagement becomes a significant influencer of LSS Project Initiation not because of the hypothesised direct effect (the hypothesis being H1). The direct effect (= 0.142, as shown in Figure 8.6) was not supported at 0.05 significance level ($p$ = 0.065), but one can view the test result as weak support of the direct effect (since $p < 0.10$) having a practically negligible/small effect (Cohen's $f^2$ = 0.08). Based on the results, Leadership Engagement becomes a significant influencer of LSS Project Initiation because of the practically significant link via the Leadership Engagement → CI Culture → LSS Project Initiation mediation link. What this seems to imply is that the role of the leadership is to engage in the project to create a culture of CI to inspire robust project initiation by the organisation's members to launch the project well. This means that leaders ought to be actively involved in promoting and embodying the principles of CI. Leadership Engagement in this context goes beyond mere endorsement of a project (the seal of approval); it involves demonstrating commitment to LSS principles, providing resources, encouraging collaboration, and recognising achievements in CI efforts. Such a leadership behaviour could motivate the team members to direct their efforts towards a common good and induce new members to follow the way in which activities are organised and done in the organisation to improve quality. Accordingly, the study recommends organisations that seek to build a culture of CI to get the leaders more engaged in LSS projects.

***Key Drivers and Influencers of LSS Project Execution***

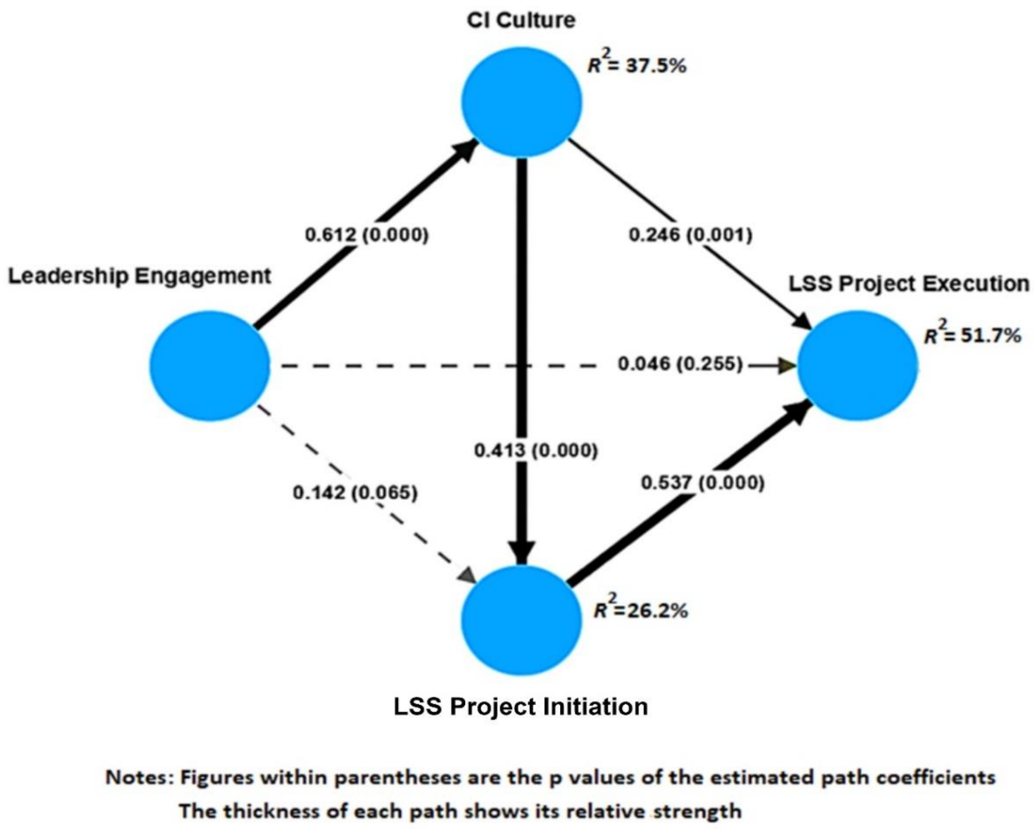



**Figure 8.6 The drivers and influencers of LSS Project Execution**

The causal antecedent of LSS Project Performance is LSS Project Execution (Figure 8.5). Therefore, from a practical perspective, it is important to know what influences LSS Project Execution. Figure 8.6 shows the drivers and influencers of LSS Project Execution, along with the strength of the hypothesised relationships. Practically important terms “drivers” and “influencers” warrant an academic clarification. A driver is a construct that does not receive incoming arrows, which in the statistical jargon is known as an exogenous variable. Thus, in a causal-predictive sense, it is the driver that causes everything to happen. The influencers are (from a practical perspective) other constructs that significantly affect what is being explained (in this instance, LSS Project Execution).

The results (Figure 8.6) show the following: Leadership Engagement is the only driver and LSS Project Initiation is the key direct influencer of LSS Project Execution (direct effect = 0.537, $p < 0.001$); CI Culture is a weaker direct influencer of LSS Project execution (direct effect = 0.246, $p = 0.001$), but because CI Culture directly and indirectly affects LSS Project Execution, its overall effect (total effect) of 0.467 on LSS Project Execution[31] is not far behind that of LSS Project Initiation. One may pose the question, which influencer is more important in executing an LSS Project: CI Improvement Culture or LSS Project Initiation? The researcher's answer to this question would be, computationally speaking the latter but both practically and theoretically speaking, the former without a doubt. This is because without a strong CI Culture, an LSS project cannot be initiated well enough to execute the project well (this is what the theory posits). Also, practically speaking, if a strong CI Culture is not present, it takes a long time to establish a strong culture to implement LSS projects successfully. On the other hand, if a strong CI Culture does exist and project initiation goes wrong on a particular occasion (unfortunate things can happen at the best of times), the researcher's theory explains that such an event would likely be a rare event. This is because the theory posits a strong relationship between Leadership Engagement (cause) and CI Culture (effect).

The implications highlighted in this section are nothing new to the quality management fraternity. For example, quality advocate Deming emphasised the role of leadership in creating a culture of CI, which has been explained comprehensively by Anderson et al. (1994); likewise, the practitioners who use the Deming's Plan-Do-Study (Check)-Act cycle of CI know that a lot of work needs to be done in the "plan" stage (in the researcher's theory the equivalent stage is LSS Project Initiation), including selecting the right project for improvement, developing aims, describing the current process, collecting data on process performance, identifying potential causes, and working out the intervention needed to address the root causes before the do stage (in the researcher's theory the equivalent concept is LSS Project Execution) should begin, suggesting a strong cause and effect relationship between initiation and execution. What the researcher's theory and test results show are the alignment of LSS project implementation (i.e., initiation and execution) with general quality improvement theory and practice.

[31] Direct effect is 0.246; the indirect effect is 0.423*0.517, which is 0.219 (Table 7.12 in the previous chapter reports the indirect effect as 0.221, the difference being attributable to rounding off). The total effect of CI Culture on LSS Project Execution is therefore 0.246 plus 0.221 = 0.467).

*The Question of Project Risk, Risk Mitigation, and the Project Residual Risks*

This aspect was covered earlier (section 8.2.3). The low mean score for Project Residual Risks suggested that practitioners seem to have attempted to mitigate risk. The test results showed that whatever risk remained (i.e., Residual Risks) does not moderate what LSS Project Execution does on LSS Project Performance. What the researcher posited was that the Project Residual Risks do interact with LSS Project Performance to cause a moderation. Figure 8.7 shows what was hypothesised and what was observed in relation to residual risks. Finding no moderation (i.e., absence of a two-way interaction, as shown by the two nearly parallel lines in the right-side panel of Figure 8.7) effect is a positive outcome because this means that an increase in Project Residual Risks does not disproportionately affect LSS Project Performance. However, as mentioned earlier, the results show that Project Residual Risks have a reducing (subtractive) effect on the improvement.

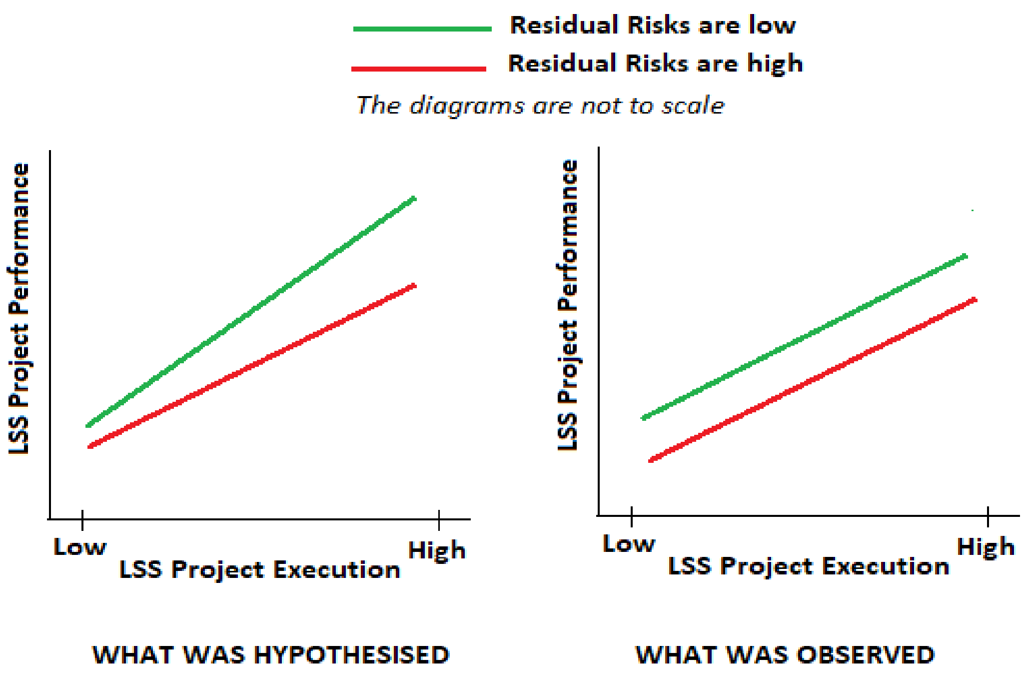



**Figure 8.7 Hypothesised versus observed, in relation to Project Residual Risks**

### 8.2.5 Achieving Objective 5: Examine whether it is possible to support the hypothesis that LSS fits to nonmanufacturing as well as it would for manufacturing at a theoretical level.

The final hypothesis of this study (H9) is that "the LSS model fits to nonmanufacturing as well as it would to manufacturing at a theoretical level". The rationale for the hypothesis is that although Lean and SS originated in manufacturing and many Lean and SS concepts are much more straightforward in manufacturing than in nonmanufacturing, the manufacturing-heavy Lean and SS concepts have been translated to simplified ways to make Lean, SS, and LSS equally applicable (hopefully) across both sectors. For example, as argued in section 2.6.2, SS is translated into a leadership-driven structured problem-solving method of CI which should apply equally well to any industry.

As part of testing H9, a multigroup analysis (MGA) was employed within the PLS-SEM framework (section 7.9) to answer RQ3 to achieve objective 5. Measurement invariance across groups (in this study, manufacturing versus nonmanufacturing) is an important requirement in MGA for the interpretations to become accurate, but this could only be established partially, based on the results. The partial measurement invariance means that some aspects of the LSS model apply universally across industries, but the remaining aspects may remain context specific. More specifically, it was found that the locations (mean values) of LSS Project Initiation and LSS Project Execution were different across the two groups.

The MGA suggested that at 0.05 significance level, there is no difference between the manufacturing sector and the nonmanufacturing sector for all but one hypothesised path. The strength of the LSS Project Execution → LSS Project performance path was found to be stronger for the nonmanufacturing sector over the manufacturing sector, to imply that for the same level of LSS Project Execution, the nonmanufacturing sector gains more than the manufacturing sector (difference = 0.217, $p = 0.032$). However, because the analysis was done under the condition "partial measurement invariance", the reason for this discrepancy could be due to measurement discrepancies. It is concluded that H9 is supported by data to some extent, but the result is inconclusive, and the recommendation was that more research needs to be done to understand whether there are any differences across the two groups on model fit as well as location differences.

Having presented what was achieved against the research objectives, the researcher now moves to present a very important aspect: contribution of the study to academia.

## 8.3 Contributions to Academia

### 8.3.1 Harmonising Fragmented Literature in Novel Ways to Formulate a Theory

The researcher found that the literature on LSS has focused less on theory building compared to the literature on SS. Yes, hypothesising and testing "implementation of Lean practices and SS practices lead to improved performance" is theory; but is it good theory? Questions such as where to start an improvement project and the soft elements of improvement such as the culture and leadership are missing (or latent) in these LSS theorisations. However, the researcher found that LSS literature is not short of prescriptions of CSFs of LSS implementation success. The researcher used the many different prescriptions of CSFs provided in a wide variety of articles pertaining to many industries (hence a large volume of information) to generate meaningful building blocks of LSS (creation of categories may be a better phrase) using ML to form the theoretical foundations of LSS (published in Perera *et al.*, 2021). Then, the researcher went on to reconcile this finding with the extant theorisations on SS (e.g., Arumugam *et al.*, 2016; Linderman *et al.*, 2006; Schroeder *et al.*, 2008; Sin *et al.*, 2015a; Zu *et al.*, 2008b). This approach was justified on the grounds that LSS and SS share many similarities as project-by-project problem solving approaches.[32] The outcome of harmonising the fragmented literature on LSS with existing theorises of SS resulted in the researcher's theoretical model.

The approach used by the researcher (literature synthesis using ML based on the researcher's algorithm and literature synthesis using the traditional method to harmonise these two literature synthesis methods) is novel and academically useful. The approach can be generalised to many other fields within and outside operations management.

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[32] Both approaches require leadership engagement for project selection, both rely on improvement experts, both use structured problem-solving methods to a greater or lesser extent, etc.

### 8.3.2 The Theoretical Model Development

It is argued that the researcher's theory (presented as a model in Figure 6.1 for ease of exposition) possess all the elements prescribed by theory-building authorities (e.g., Dubin, 1978; Whetten, 1989) to constitute a theoretical contribution. Firstly, the model is novel, but it is not built from scratch. This makes it easier for the researcher to show how her study extends the current body of knowledge on LSS. The model that is closest to the researcher's model is the untested model on SS posited by Schroeder *et al.* (2008). The driver and the explained variable (Leadership Engagement and Project Performance respectively) of both models are the same but the mediation mechanism of the two models —though reconcilable—are different. In addition, the researcher considers inherent risk of a project (more precisely Project Residual Risks) as a building block (a construct) of her theory, in that this risk acts as a moderator in the execution → performance link. Attempting to understand how the residual risk of a project affects outcomes is something that has not been done in SS or LSS fields. Equally importantly, the researcher clearly delineated how the building blocks of her theory (the constructs) relate to one another.

Finally, the researcher defined the boundary conditions of her theory. The researcher specified that her theory applies at project level and not organisational in that while her theory can explain why an LSS project had failed (or succeeded), her theory cannot explain why organisations who labels themselves as LSS organisations sometimes fail. Similarly, the researcher specified that her theory would not cover some LSS projects that an organisation may proclaim as an LSS projects, because for the researcher's theory to be applicable, a project must have the potential to yield a certain threshold return on investment, because otherwise Leadership Engagement isn't going to happen (see section 3.5.1 for details).

### 8.3.3 Implications of Hypothesis Test Results

The study found that a variety of LSS project definitions, reporting structures, and deployments of quality improvement specialists in the industry (Chapter 5). The empirical test results of the eight hypotheses that constituted the researcher's theory indicated that the researcher's theory is flexible enough to fit to data[33] that would have come from many different settings. This

[33] Based on the conventions used in PLS-SEM.

coupled with other findings, particularly showing how the Project Residual Risks affect LSS Project Performance and showing partial support to the hypothesis “the LSS model fits to non-manufacturing as well as it would to manufacturing at a theoretical level” are important contributions to academia (new knowledge).

## 8.4 Contributions to the Practice of LSS

### 8.4.1 The Researcher’s Operational Definitions

Operational definitions are not only important for quantitative researchers to test theory and make predictions, but they are also useful for managers. There are six concepts (constructs) associated with the researcher’s measurement framework. Most labels given by the researcher for her constructs—perhaps, with the exception of Project Residual Risks—have common sense meaning. Often managers think they know what these concepts mean (at least quality improvement fraternity will have some idea about it, some much better than the others), but often managers will fall short of fully understanding what a particular concept means. A good example is the meaning of CI Culture. What this exactly means in LSS is comprehensively defined by the researcher (the reader may want to refer to the measurement framework of the constructs given in Appendix D). Likewise what Leadership Engagement means is operationally defined by researcher. The operational definition (and the conceptual definition) can be suitably expanded when necessary. How this has been done for Leadership Engagement is given below in very descriptive fashion.

Ledership engagement in the context of LSS is less about directing specific tasks and more about creating a culture in which LSS principles are deeply ingrained. This involves not only adherence to LSS principles but also demonstrating these principles in leadership behaviours, decision-making processes, and organisational structures. This creates an environment where the workforce is encouraged and motivated to integrate Lean and SS practices into their daily operations. Such a leadership style fosters a proactive, problem-solving mindset among the followers, which is crucial for organisational learning. To achieve the culture shift, comprehensive training programmes must be developed and implemented to improve technical skills related to Lean and SS (the hard skills) as well as relational skills, addressing issues such as changing the followers’ mindset and attitudes toward work processes. By participating actively in training programmes, reinforcing the importance of CI principles (e.g., teamwork, respect for people), and recognising and rewarding CI behaviours and initiatives, leadership plays a crucial role in the cultural transformation.

For the aforementioned reasons, the researcher suggests that her operational definitions would provide a complete picture of enablers that need to exist for LSS Project Performance (without loss of generality, quality performance) to achieve the requisite level.

A comprehensive set of operational definitions for LSS building blocks (constructs) also means that managers can develop a reliable performance measurement system (including a scoring system) to gauge how they are doing in LSS projects over time. However, the researcher admonishes practitioners that such a performance measurement system should be integrated with the organisation's high-level performance measurement system. For example, if an organisation uses the Balance Scorecard (Kaplan & Norton, 2001), for strategic planning purposes, the LSS performance measurement system should be consistent with the strategic objectives and performance metrics placed in the internal operations quadrant of the Balance Scorecard.

### 8.4.2 The Researcher's Model for Guidance

A good theory (model) is not only a good theoretical contribution but is also a good practical contribution. A theory provides the explanation and prediction, and the researcher's theory is no different. The researcher's theory explains what causes success or failure and how, regarding implementation of an LSS project.

Based on the researcher's theory, Leadership Engagement drives the system. Therefore, if the leadership of an organisation is not engaging in LSS projects adequately, LSS projects are doomed to fail. The model shows that more the leaders engage in LSS projects, the stronger the CI Culture becomes. This is important to the practitioner because there will be occasions where Leadership Engagement will be low for a particular LSS project in an organisation that has a strong CI Culture. The researcher's theory/model explains that some damage would be done[34] then because Leadership Engagement has a direct effect on LSS Project Initiation. However, the researcher's theory/model also explains that even if the leadership does not engage adequately for a particular LSS project in an organisation that has a strong CI Culture (this would be a rare occurrence as agued earlier), there is still a good chance of the project being able to achieve a reasonable outcome. This is because CI Culture will try and carry the project over the line (the strong culture is not going to change just because the leadership engagement was low for a particular project). An engineer may call this the inertia and CI Culture would then play the role of the "flywheel" (and other mechanical parts that retain the inertia) of an automobile.

Another important benefit the researcher's theory/model offers to managers is its simplicity and alignment to project management. There is no organisation that does not implement projects to achieve its goals. Thus, project management is in the experience of managers (practitioners in general). As mentioned at the beginning of this chapter, the researcher's theory/model is simple enough to demonstrate that an LSS project needs to be executed well to achieve requisite performance outcomes, yet it is sophisticated enough to show what causes successful project execution.

### 8.4.3 Practical Implications that Stem from Hypothesis Test Results

The hypothesis test results of a well-specified model are useful for the practitioners. The practitioners of LSS would be familiar with basic statistical techniques such as multiple regression modelling. They can interpret the results of each set of explanatory and explained variables (constructs) to interpret what the prediction means (e.g., the $R^2$). To enumerate this, the reader's attention is drawn to Figure 8.5, which shows the predictors of LSS Project Performance—LSS Project Execution, Project Residual Risks, and the two-way interaction term LSS Project Execution*Project Residual Risks—along with path coefficients and the coefficient of determination (the $R^2$) associated with the explained variable. Consider the $R^2$, which is 35.5%. The results imply number of things. Firstly, despite having three explanatory variables, they explain only 35.5% of the variability of LSS Performance. This implies that other uncontrollable factors such as actors (e.g., competitors) and forces (e.g., government and

[34] Not so much perhaps, because the Leadership Engagement → LSS Project Initiation direct effect is weak.

regulatory pressure, technological constraints) in the external environment play a sizable role in the outcome. The strong path coefficient of 0.543 suggests that all other things remaining the same (notably Project Residual Risks) if the execution can be improved by 1%, the practitioner expects an improvement of 0.543% in the outcomes, which most practitioners would consider as a reasonable expectation. The practitioners would also be pleased to know that the size of the organisation and its broad sector (manufacturing vs nonmanufacturing) do not affect results.[35] As explained in the previous chapter these variables were considered in the modelling as control variables but were removed from the model as they explained virtually nothing, in terms of the increase in the $R^2$ value of LSS Project Performance (the regression coefficients of the control variables were also nonsignificant).

Another important finding that the managers would appreciate is that the results show the key causal path (the reader may want to examine test results shown in Figure 7.17), which happens to be: Leadership Engagement → CI Culture → LSS Project Initiation → LSS Project Execution→ LSS Project Performance. The other causal paths act as support mechanisms, but the managers will need to focus more on the key causal path. The results also show that the overall effect of Leadership Engagement (in path modelling language the total effect) on LSS Project performance is 0.216, which is much less than what a manager may expect. The scientific reason for the attenuated effect is the long transmission path (the key causal path shown above) through which LE Engagement effect propagates to cause a change in LSS Project Performance. Another reason for the moderate effect of 0.216 is the existence of several uncontrollable nuisance factors (from a statistical sense) that are also accountable for the variability of LSS Project Performance.

## 8.5 Delimitations and Limitations of the Research

Delimitations of a study refers to the boundary or context within which the findings become generalisable. All studies or theories have delimitations; limitations on the other hand are a result of a research design, which are often dictated by the resource constraints such as funding

[35] Note that the sector was treated as a dummy variable that does not affect the regression coefficients. This is how control variables are generally used in regression (i.e., as intercept adjustors but not regression coefficient adjustors). In MGA the sector was treated differently.

and time (Mauch & Park, 2003). The delimitations of the study (boundary conditions) have been outlined by the researcher already (in this chapter as well as in section 3.5.1).

One limitation of the study is that the study does not definitely answer the conceptual question "can LSS be reliably distinguished from Lean, SS and TQM as a quality improvement approach?" The researcher posed this question in the literature review, which is a question of discriminant validity (fortunately this was not a research question posed by the researcher), but with the evidence available at hand (data and information including research findings), the researcher is unable to answer this question, even though her model represented LSS as a project implementation phenomenon. It was interesting note that out of 296 respondents 80 said they use predominantly a Lean approach; fortunately, 198 said they use a balanced approach and only 18 said they use a predominantly SS approach. The researcher's model fitted all these scenarios which raises the question: is LSS like Lycra that can be stretched to different shapes and forms to fit occasion? If this seems to be the case, there is nothing wrong (in the researcher's humble opinion), but this should be established scientifically.

Another limitation of the study (in the quantitative portion) is that although a sample size of 296 is a big sample, this sample may not be big enough to represent the population, although the sample size passed the power analysis test. Millions of organisations around the word practice LSS and one can always question whether 296 cases could represent this big and diverse population. Assuming that there are 10 million genuinely LSS organisations around the world, 296 would mean only a 0.003% representation. In any case, the researcher's sample is a nonprobability sample and hence some caution needs to be exercised by the reader in interpreting the results (one should not attempt to over-generalise the results).

## 8.6 Suggestions for Future Research

Being a quantitative dominant study, the study sacrificed some rich information in favour of statistical generalisability. Although the researcher exercised caution in releasing her questionnaire to a global sample of LSS practitioners, some degree of loss of control becomes inevitable. Although the size of the firm and the sector were considered as control variables (they were not found to have a significant effect), this kind of statistical control may not be as tight as it would be if limiting the study to a more focused sampling frame such as high performance LSS organisations. Thus, it is suggested that a future study could limit empirical testing to a more well identifiable sampling frame such as high performance LSS organisations, with some model modification/s (e.g., use of sustainability also as an LSS project outcome) to justify new knowledge.

The second suggestion is to design a piece of research to test whether LSS as a theoretical concept or framework possesses sufficient discriminant validity, to answer the conceptual question: can LSS be reliably distinguished from Lean, SS, and TQM as a quality improvement framework or approach?

The third suggestion is to re-test H9 under more controlled conditions or to conduct case studies to better understand how the proposed theory works in manufacturing and nonmanufacturing.

The fourth suggestion is to conduct exploratory research to understand to what extent LSS outcomes on products and services can be sustained by organisations. This requires a well-designed longitudinal study.

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# Appendix – A: Python Code of CSFs Classifier

## Python coding for extracting and classifying CSFs.

```
Automatically generated by Colaboratory.

Original file is located at
    https://colab.research.google.com/drive/1kUVSwoX77uMSO3rvy4uA187klOs7f1aD
"""
#Importing drive
from google.colab import drive

#Importing necessary libraries
from mlxtend.plotting import plot_confusion_matrix
from sklearn.metrics import confusion_matrix
from sklearn.manifold import TSNE
from sklearn.model_selection import train_test_split
from keras.utils import to_categorical
from tensorflow.keras.models import Sequential
from tensorflow.keras import layers
from keras import regularizers
from mlxtend.evaluate import scoring
from sklearn.metrics import f1_score
from tensorflow import keras
from sklearn.model_selection import train_test_split
drive.mount('/content/drive')

# Install the latest Tensorflow version.
!pip3 install --quiet "tensorflow>=1.7"
# Install TF-Hub.
!pip3 install --quiet tensorflow-hub
!pip3 install --quiet seaborn

#%tensorflow_version 1.x
import tensorflow as tf
print(tf.__version__)
import tensorflow_hub as hub
import matplotlib.pyplot as plt
import numpy as np
import os
import pandas as pd
import re
import seaborn as sns
import datetime

column_names = ["Headings"] # giving name to columns
iris_excel_path = "training data.xlsx" # giving path to file
data_y = pd.read_excel(iris_excel_path, "Headings",names=column_names) # the sheet name
data_y.head()

column_names= ["CSFs"] # giving name to columns
data_x=pd.read_excel(iris_excel_path, "CSFs",names=column_names) # the sheet name
data_x.head()

#Converting CSFs in to sentence list
sentence_list =data_x['CSFs'].tolist()
print(sentence_list[0:10])
```

```
# Import the Universal Sentence Encoder's TF Hub module
module_url = "https://tfhub.dev/google/universal-sentence-encoder/4"
modeltxt = hub.load(module_url)
print ("module %s loaded" % module_url)
def embed(input):
  return modeltxt(input)

# Reduce logging output.
from absl import logging
logging.set_verbosity(logging.ERROR)

txt_embeddingvec = embed(sentence_list)

#Assigning y_lable data
y_label =data_y["Headings"].tolist()
y_label
myset = set(y_label)
print(myset)

#Mappping the headings
mapping = {'Leadership Engagement':0, 'CI Culture':1, 'LSS Structure':2, 'Project Initiation':3, ‘LSS Execution':4}
data_y['Headings']=data_y.replace({"Headings": mapping})
data_y.head()
y_label =data_y["Headings"].tolist()
myset = set(y_label)
print(myset)

#creating a dataframe with y labels and CSFs
df1 = pd.DataFrame({ 'Headings': y_label, 'CSFs':sentence_list, })
df1[0:10]

#Export mapped data to an excel file
df1.to_excel("Training Data.xlsx",sheet_name='Mapping')

y=data_y['Headings'].tolist()
label =np.asarray(y)
label=np.reshape(label,(536 ,1))
print(label.shape)
train_data=np.concatenate((txt_embeddingvec,label), axis=1)
train_data.shape

#Shuffling the training data
from sklearn.utils import shuffle
X=train_data[:,:512]
Y=train_data[:,512]

print(X[0:5],Y[0:5])
X, Y = shuffle (X, Y, random_state=0)
print(X[0:5],Y[0:5])

#Splitting the training dataset into two : 80% training data (X_train, y_train) and 20%  cross-validation data (X_test, y_test)
X_train, X_test, y_train, y_test = train_test_split(X, Y,
                                                    stratify=Y,
                                                    test_size=0.20,random_state=42)
train_y = to_categorical(y_train)
csv_y = to_categorical(y_test)
```

```
# Training the model
model = Sequential()
model.add(layers.Dense(128,kernel_regularizer=regularizers.l2(0.001), activation='relu', input_shape=(512,)))
#model.add(layers.Dense(16, kernel_regularizer=regularizers.l2(0.001),activation='relu'))
model.add(layers.Dense(8, activation='softmax'))
model.compile(optimizer='rmsprop',
loss='binary_crossentropy',
metrics=['accuracy'])
log_dir = "logs/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir, histogram_freq=1)
model.fit(X_train, train_y, epochs=100, batch_size=10)
results = model.evaluate(X_test,test_labels)

#Saving the model
model.save('path_to_my_modelachi_75+.h2')

#Evaluating training results
import matplotlib.pyplot as plt
plt.style.use('ggplot')

def plot_history(history):
    acc = history.history['accuracy']
    val_acc = history.history['val_accuracy']
    loss = history.history['loss']
    val_loss = history.history['val_loss']
    x = range(1, len(acc) + 1)

    plt.figure(figsize=(15,15 ))
    plt.subplot(2, 1, 1)
    plt.plot(x, acc, 'b', label='Training acc')
    plt.plot(x, val_acc, 'r', label='Validation acc')
    plt.title('Training and validation accuracy')
    plt.legend()
    plt.subplot(2,1, 2)
    plt.plot(x, loss, 'b', label='Training loss')
    plt.plot(x, val_loss, 'r', label='Validation loss')
    plt.title('Training and validation loss')
    plt.legend()

history = model.fit(X_train, train_y, epochs=40, verbose=False, validation_data=(X_test, csv_y), batch_size=15)
loss, accuracy = model.evaluate(X_train, train_y, verbose=False)
print("Training Accuracy: {:.4f}".format(accuracy))
loss, accuracy = model.evaluate(X_test, csv_y, verbose=False)
print("Cross Validation Accuracy:  {:.4f}".format(accuracy))
y_pred_csv = model.predict_classes(X_test)
plot_history(history)

from sklearn import metrics
# Print the precision and recall, among other metrics
print(metrics.classification_report(y_test,  y_pred_csv, digits=3))

confusion_matrix = confusion_matrix(y_test, y_pred_csv )
fig, ax = plot_confusion_matrix(conf_mat=confusion_matrix, figsize=(15, 15))
plt.show()
```

```
#Predicting and testing the accuracy of the predictions
column_names = ["Test CSFs","Actual","Predicted"] # giving name to columns
iris_excel_path1 = "Test data.xlsx"
data_test = pd.read_excel(iris_excel_path1, "Test CSFs", names=column_names) # the sheet name add here

test_sentence_list =data_test["Test CSFs"].tolist()
test_sentence_list[0:10]

# Import the Universal Sentence Encoder's TF Hub module
#logging.set_verbosity(logging.ERROR)

txt_embeddingvecNew = embed(test_sentence_list)
 # txt_embeddingvecNew = session.run(embed(test_sentence_list))

txt_embeddingvecNew.shape

x_test=np.asarray(txt_embeddingvecNew)
y_pred = model.predict_classes(x_test)
y_pred.shape
y_pred[0:5]

df = pd.DataFrame({ 'Test CSFs':test_sentence_list, 'Predicted': y_pred.flatten()})
df[0:10]

df.to_excel('predictions.xlsx')

y1=y_pred.tolist()
label1=np.asarray(y1)
print(label1.shape)

label1=np.reshape(label1,(1936 ,1)) # give dim to concatenate with features
full_data2=np.concatenate((txt_embeddingvecNew,label1), axis=1) # combine to shuffle data
np.random.shuffle(full_data2)
Finaltest_X1=full_data2[:,:512]
Y1=full_data2[:,512]
Finaltest_Y1 = to_categorical(Y1)
print(Finaltest_Y1.shape)
print(Finaltest_X1.shape)

Final_results = model.evaluate(Finaltest_X1,Finaltest_Y1)

y_pred_csv2 = model.predict_classes(Finaltest_X1)

confusion_matrix2 = confusion_matrix(Y1, y_pred_csv2 )
fig, ax = plot_confusion_matrix(conf_mat=confusion_matrix2, figsize=(5, 5))
plt.show()


history = model.fit(X_train, train_y, epochs=100, verbose=False, validation_data=(Finaltest_X1,Finaltest_Y1),
batch_size=30)
plot_history(history)

loss, accuracy = model.evaluate(X_train, train_y, verbose=False)
print("Training Accuracy: {:.4f}".format(accuracy))
loss, accuracy = model.evaluate( Finaltest_X1,Finaltest_Y1, verbose=False)
print("Test Accuracy:  {:.4f}".format(accuracy))

Xtsne = Finaltest_X1
Xtsne_embedded = TSNE(n_components=2).fit_transform(Xtsne)
```

```
# Commented out IPython magic to ensure Python compatibility.
# %matplotlib inline
fig, axes = plt.subplots( figsize=(10, 10))
scatter = axes.scatter(Xtsne_embedded[:,0],Xtsne_embedded[:,1], c=Y1)
# produce a legend with the unique colors from the scattero
legend1 = axes.legend(*scatter.legend_elements(),loc="lower left", title="Classes")
axes.add_artist(legend1)
#,label=mapping
plt.show()


#from sklearn.manifold import TSNE
#Xtsne1= train_data[:,:3]
#Xtsne_embedded1 = TSNE(n_components=2).fit_transform(Xtsne1)
#plt.scatter(Xtsne_embedded1[:,0],Xtsne_embedded1[:,1])

#Xtsne_embedded1.shape
column_names = ["Actual"] # giving name to columns
column_names = ["predicted"] # giving name to columns
iris_excel_path1 = "actual.xlsx"
data_expert = pd.read_excel(iris_excel_path1, "actual", names=column_names) # the sheet name add here
data_pred = pd.read_excel(iris_excel_path1, "pred", names=column_names) # the sheet name add here

from sklearn import metrics
# Print the precision and recall, among other metrics
print(metrics.classification_report(data_pred,  data_expert, digits=3))
```

# Appendix – B: Documents Related to Semi-Structured Interview

## Interview Invitation

Dear colleague,

Developing and Testing the Theoretical and Practical Underpinnings of Lean Six Sigma

I am Achinthya Perera a doctoral student in industrial engineering from Massey University, Palmerston North, and New Zealand. My research, titled above, is being supervised by Dr Nihal Jayamaha, Professor Nigel Grigg and Dr Mark Tunnicliffe. My research is supported by a full scholarship from Massey University. I am trying to contribute to the current body of knowledge on Lean Six Sigma (LSS) by developing and testing precise and scientific explanations of LSS as a quality improvement and business process improvement approach. An academic community may view my work as LSS theory development and testing, while a practitioner may view my work as an attempt to explain to the practitioner world what enablers are required and how they work in providing better LSS outcomes for manufacturing and service businesses (I am excluding the government and non-profit sector).

One of my research challenges are understanding as vividly as possible, how the industry understands LSS (for example how they distinguish a Six Sigma project from a Lean Six Sigma project). Another challenge I have is sharpen by knowledge on the enablers of LSS (critical success factors) by trying to understand how these enablers are manifested (displayed) in the practice of LSS. For example, everybody knows that LSS execution is an important phase (enabler/critical success factor) in LSS, but how do practitioners gauge that LSS execution is taking place smoothly? To successfully meet my above research challenges, I need industry input from experienced practitioners such as you. Once I have a full understanding of LSS and its enablers and how the industry validates successful LSS outcomes (phase 1 of my study) I can easy test my theories and models in the next phase of my study (phase 2) using quantitative (statistical) research techniques involving large samples from major countries.

In phase 1 of my, I in need to interview about 10 experienced LSS practitioners (about six from New Zealand and four from Australia) form different manufacturing and service businesses. I am seeking your support in this connection. The interview will take "semi structured form" and the schedules of questions that I intend to ask you are attached to this letter. I would imagine that I can cover the interview in one sitting, and I anticipate the interview to last 45 minutes to 1 hour. It would be appreciated if you could let me know if you are able to attend my interview.

Needless to say, all responses shall be confidential, and I shall use the information that you provide for my PhD research. I shall ensure the anonymity of respondents and their organizations at all times. I hope to send a short report on what I found to my valuable participants.

This research is conducted in accordance with Massey University Human Ethics Committee guidelines. My research has been peer reviewed and deemed to be "low risk". If you have any questions or concerns about the interview, please do not hesitate to contact me. I have mentioned the contact emails of my supervisors, in case you want to write to them directly.

I thank you in advance for your participation and support in making my research project a success. I look forward to hearing from you at your earliest convenience on your willingness to participate in the interview.

Sincerely,

……………………………………….

Achinthya Perera
Email: A.Perera@massey.ac.nz | Tel: (06)3569099, Ext:

Contact emails of my supervisors if applicable:

1. Dr Nihal Jayamaha: N.P.Jayamaha@massey.ac.nz
2. Professor Nigel Grigg: N.Grigg@massey.ac.nz
3. Dr Mark Tunnicliffe: M.C.Tunnicliffe@massey.ac.nz

## Interview Consent Form

The interview will be digitally recorded for the above extensive research, and you will be given the opportunity to review and modify the transcript in due course. Any personal details will be anonymised, and I will not deliberately disclose your identity to anyone outside the study supervision team.

The contents of the interviews – including yours – will be analysed and written during the course of the research. The results may be included later in the University Library's published thesis, academic conference papers and journal documents. Neither your own name, the name of the organization, nor any of your other personal details that would identify you will ever be associated with these quotations.

I would be thankful if you could verify that you are happy to participate in this interview or extracts from it in this manner by signing this form.

Consent: I AGREE to participate in this research.

Name of Interviewee (Block Capitals): ________________________________

Interviewee Signature: ____________________________ Date: ___________

## Semi Structured Questionnaire to Interview Industry Participants: Understanding the Practical Underpinnings of Lean Six Sigma

Following are the questions that I am going to ask you, for which verbal responses are solicited. There are two parts to this questionnaire. In Part A I am attempting to gather information about the practice of LSS based on your experience. Some questions are about the background of you and your company; this is for my own sanity. In Part B I am attempting to understand the enablers of LSS that I have come across through my literature synthesis, from an industry perspective. Your responses to Part B will enable be to develop a reliable quantitative survey questionnaire later to test my propositions involving LSS enablers and results (quality and business results associated with LSS projects).

Part A

1. How would you best describe your core business?
2. How long has your organization been practicing the LSS?
3. What is your designation in the above organization?
4. What are the major responsibilities of you position?
5. How long have you been working with LSS projects — from your first ever major project (this could have been in another organisation) through to your last project?
6. How would you define an LSS project? In what ways does an LSS project differ from standard continuous improvement initiative such as PDCA?
7. How do lean and six sigma components complement each other in an LSS project?
8. Think about your most recent LSS project. What led you/your organisation to select this project?
9. How did you ensure that this project is the right project at the right time to deliver the right results?
10. In your experience on all the LSS projects in which you had a hand on, how changing it is to sustain improvements that you initially attained through an LSS project.

Part B

I am taking you through four important stages of an LSS project. Thereafter, I will ask you what contingency factors affect LSS outcomes and how you assessed these outcomes: quality outcomes, customer satisfaction and business results. I am using the word “manifest” in Part B to mean demonstrated or seen.

1. **Leadership Engagement: Suggest 4-6 ways leadership engagement manifests in an LSS project**. E.g. If the leadership engagement is low you may be able to see that by their minimal involvement/enthusiasm in resource allocation decisions.

   (a)……………….

   (b)……………….

   (c)………………….

   (d)………………….

   (e)…………………..

   (f)……………………

2. **LSS Project Initiation: Suggest 4-6 ways LSS project initiation manifests in practice**. E.g. How will you know that voice of the customer is being heard? How will you know that voice of the process is being captured? How will you know that voice of the customer is being heard? How will you know that voice of other stakeholders is being heard?

   (a)……………….

   (b)……………….

   (c)………………….

   (d)………………….

   (e)…………………..

   (f)……………………

3. LSS Structure: Suggest 4-6 ways one can see whether or not an effective structure is being put in place an organisation for LSS to work. *E.g. Rather than relying on a six-sigma black belt(s) to do everything, an organisation may develop systems in place to ensure contribution from multidisciplinary experts for successful problem solving.*

(a)……………….
(b)……………….
(c)………………….
(d)………………….
(e)…………………..
(f)……………………

4. **LSS Execution: Suggest 4-6 ways LSS execution manifests in an LSS project**. E.g. If DMAIC process is being executed well you may establish criteria to ensure that each step of DMAIC passes is being executed well.

(a)……………….
(b)……………….
(c)………………….
(d)………………….
(e)…………………..
(f)……………………

5. **Contingency Factors. Name 2-4 contingency factors that can have a bearing on LSS outcomes.** E.g. If the project is complex, for the same level of LSS execution (hypothetically), you may expect less results. Stated alternatively, for a complex project to deliver results, you may intensify LSS execution.

(a)……………….
(b)……………….
(c)………………….
(d)………………….

6. **Quality Performance. Name 2-4 quality goals that are applicable to <u>any</u> LSS project.** E.g. No project may be an LSS project of reducing variation is not a quality goal. Note that reducing variation can manifest in many ways. For example reducing the defects count equates to reducing variation.

(a)……………….
(b)……………….
(c)………………….

(d)………………….

7. Customer Satisfaction. Name 2-3 different ways that you can always use to ensure that your purchasing customers (external customers) are satisfied with what you provided them through your LSS project. *E.g. There may be less warranty claims after improving the quality performance.*

(a)……………….
(b)……………….
(c)………………….

8. Business Performance. Name 2-4 business performance metrics that are applicable to any LSS project. *E.g., Return on Investment may be something that a business always pursues in an LSS project.*

(a)……………….
(b)……………….
(c)………………….

Wrapping up the Interview

Do you have any comments on any of the items that I have included in this interview schedule?

**********Thank you, this is the end of this interview schedule*********

# Appendix – C: Details of Case Organisations

## Case Organisation 1(MO-1)

A leading healthcare provider and manufacturer, MO-1 strives to improve the lives of patients, whether in a hospital or at home. With over 15 years of experience in LSS, the respondent possesses an LSSBB certification and holds the position of General Manager of Business Excellence at MO-1. MO-1 has become a global leader by being committed to improving patient outcomes. Its journey towards operational excellence dates to the 1980s when the organization adopted Lean manufacturing principles wholeheartedly. As part of its continuous pursuit of excellence, MO-1 expanded its quality improvement initiatives to include Lean Six Sigma (LSS) methodologies 19 years ago. Over the years, MO-1 has completed hundreds of LSS projects. MO-1 has accumulated experience in implementing LSS projects over the years, but exact figures may vary. Over the last several decades, they have refined healthcare practices for the benefit of patients around the world through continuous improvement.

## Case Organisation 2(NMO-2)

The lower North Island is served by approximately 140,000 residents of NMO-2. As a healthcare organization, NMO-2 is dedicated to delivering outstanding healthcare services and maintaining its members' well-being. With over 10 years of experience in the field, the respondent from NMO-2 holds an LSSMBB certification and holds the role of Improvement Advisor (Consultant). While they are primarily focused on patient care and outcomes, they have recently adopted Lean Six Sigma (LSS) methodologies to transform their organization. With approximately six years of experience, NMO-2 has demonstrated its commitment to process improvement. Although NMO-2 is in its initial stages of adopting LSS, it has made substantial progress in implementing the principles to enhance healthcare services. Throughout their journey, the team has completed approximately 25 projects, demonstrating their commitment to improving patient care through LSS. With continued development and refinement of LSS practices, NMO-2 is well positioned to contribute to improving healthcare quality and efficiency in their region.

## Case Organisation 3 (NMO-3)

NMO-3 operates under the well-known Supermarkets brand and is a cornerstone of New Zealand's retail landscape. With a legacy of serving Kiwi communities for generations, NMO-

3 has consistently evolved to meet its customers' ever-changing needs. Its commitment to innovation and process excellence shines through its its initiatives and projects. The respondent from NMO-3 has been leading the process improvement team as an external consultant to orchestrate change across all business units within NMO-3's vast ecosystem. Over the past decade, NMO-3 has applied CI methodologies such as LSS to Store Operations and other functions at the national and zone levels.

## Case Organisation 4(MO-4)

The MO-4 Group has been in the heating and cooling industry in New Zealand for several decades. As a subsidiary of the global Group, the company has access to extensive knowledge and technology. With a wide range of products that are tailored to meet the varied needs of New Zealanders' climate and lifestyle, they demonstrate their commitment to sustainability and energy efficiency. With the LSS methodology, MO-4 has enhanced product and customer service quality for nearly 12 years. MO-4's relentless pursuit of excellence has made it a leading heating and cooling company in New Zealand. With its nationwide dealer and technician network, MO-4 delivers unparalleled customer service. The respondent from MO-4 has experience in LSS for more than 15 years and has an LSSMBB certification.

## Case Organisation 5(NMO-5)

As specialists in productivity enhancement, NMO-5 has mastered the art of unlocking untapped potential within businesses, improving performance across a variety of industries in Aotearoa. They serve a variety of clients, ranging from small businesses to large organizations. Their approach focuses on unpacking Lean Six Sigma (LSS) and Operational Excellence initiatives and providing insights into how to enhance productivity through these programs. As a trusted partner to businesses seeking operational excellence, NMO-5 helps clients optimize processes, reduce waste, and boost productivity. By providing organizations with the tools and knowledge for continuous improvement, they have become an essential force behind the increasing productivity of New Zealand's business landscape. In particular, the participant from NMO-5 has been involved in LSS for nearly twenty years in a variety of industries and even in other countries.

## Case Organisation 6(MO-6)

As a leading innovator and innovator in the steel industry, MO-6 has demonstrated a profound commitment to continuous improvement (CI). Since implementing Lean and Six Sigma methodologies over the past fifteen years, MO-6 has greatly impacted its operations. In the beginning, their primary goal was to implement Lean principles. Through their remarkable journey, MO6 has consistently strived for operational excellence. By utilizing Lean and Six Sigma, they have been able to enhance efficiency and quality across their processes. CI has enabled MO-6 to not only transform its internal operations, but also set new standards for the industry as a leading player in the steel industry. To maintain their leadership position in the global steel market, MO-6 remains committed to Lean and Six Sigma methodologies, driving innovation and excellence.

## Case Organisation 7(MO-7)

MO-7 is an Australian company with a prominent name in the world of winemaking and has embarked on an impressive journey of Continuous Improvement (CI). Their commitment to excellence and innovation can be seen in the numerous Continuous Improvement initiatives they undertake. In their pursuit of operational excellence, MO-7 has moved into the realm of Lean Six Sigma (LSS) projects 14 years ago marking an important milestone in their journey. With 16 wineries in Australia, two in New Zealand, and a state-of-the-art packaging facility in the UK, MO-7 produces an astonishing 34 million cases of wine annually. The company has an even broader global reach, with operations spanning the globe and the ownership of 45 prestigious brands.

## Case Organisation 8(NMO-8)

NMO-8 is the pioneering force behind the Australia’s broadband network and has embarked on a transformative journey towards operational excellence. Their continuous commitment to improving telecommunications services in Australia has been underscored by their journey into LSS, which commenced in 2014. However, their dedication to Lean management principles dates back even further, with foundational experiences dating as far back as 2008. As Australia's leading broadband infrastructure provider NMO-8 plays a pivotal role in shaping the nation's digital landscape. Their journey into LSS represents a strategic move to enhance the efficiency, reliability, and quality of their services. With a focus on delivering top-notch broadband connectivity to households and businesses across the country, NMO-8's dedication to LSS principles is a testament to their unwavering commitment to providing Australians with world-class telecommunications solutions.

### Case Organisation 9(MO-9)

MO-9 is a prominent player in the heating, ventilation, and air conditioning (HVAC) industry, and has a rich history of innovation and excellence. With roots in Japan, MO-9 has emphasized Lean Manufacturing in its journey to operational excellence through continuous improvement. Lean Manufacturing principles have been used by them for over a decade to continuously improve processes, improve product quality, and streamline operations. Lean Six Sigma (LSS) was an evolution of MO-9's commitment to efficiency and customer-centricity two decades ago. MO-9 recognized that quality and process improvement needed to be more comprehensive, building upon their solid foundation in Lean Manufacturing. It gave them the right framework to combine Lean principles with data-driven decision-making, enabling them to deliver better HVAC solutions. It signifies a pivotal moment in MO-9's quest for operational excellence that the transition to LSS marks the beginning of this dynamic journey. By combining the power of Lean Manufacturing with the analytical rigour of Six Sigma, they are poised to deliver cutting-edge HVAC products as well as unmatched quality and reliability, reinforcing their position as an industry leader committed to exceeding customer expectations.

### Case Organisation 10(NMO-10)

In the insurance industry, NMO-10 has a long history of providing dependable coverage to millions of customers nationwide. They have been striving towards operational excellence for many years due to a strong focus on Lean Manufacturing practices. NMO-10 has consistently strived to improve efficiency, reduce waste, and provide the highest quality service. As a result of NMO-10's commitment to continuous improvement, Lean Six Sigma (LSS) became the pivotal moment in their commitment. They realized, after successfully integrating Lean principles into their operations, that data-driven decision-making would enable further optimization. As a result of this, their first Lean Six Sigma project was initiated, marking a significant milestone in their pursuit of excellence. The training and development of 16 LSS Blackbelts, including the respondent, underscores NMO-10's commitment to equipping the workforce with the skills and tools necessary for implementing transformative change. In addition to providing insurance solutions, they strive to deliver superior quality and efficiency in their operations through this proactive approach. As they harness the combined power of Lean Manufacturing and Six Sigma methodologies, NMO-10 is well-positioned to continue their legacy of providing exceptional service to its valued customers.

## Case Organisation 11(MO-11)

MO-11 is a global aerospace giant that embarked on a transformative Lean Six Sigma (LSS) journey in 1990, which marked a significant turning point in its long history. MO-11 faced a pressing need to ramp up aircraft production rates as the impetus for this undertaking. At that time, MO-11 faced the challenge of accelerating production without compromising quality. To reach this ambitious goal, it would require an increase in output, but also highly qualified personnel. MO-11 needed innovative solutions, so they contacted an industry leader with a reputation for implementing Lean manufacturing methods. Through intensive training provided by seasoned coaches, MO-11's executives embarked on a remarkable journey to learn from the experts in the industry. Through these daily classroom sessions at MO-11, the tenets of Lean manufacturing were transferred into the company culture daily. This transition to updated systems was no small feat, and it took MO-11 a decade to fully integrate Lean Six Sigma into its operations. Once the engineers had become familiar with Lean Six Sigma principles, MO-11's performance began to grow substantially as a result of their perseverance. There is no doubt that MO11's remarkable journey is testimony to the power of Lean Six Sigma methodologies to promote efficiency, quality, and competitiveness in the aerospace industry, reaffirming the company's position as a global leader in the industry.

## Case Organisation 12(NMO-12)

A US-based company, NMO-12, has undertaken a transformation fuelled by Lean Manufacturing and LSS. As a result of its rich history of agricultural excellence, this organization recognized the need to utilise modern methodologies to achieve continuous improvement. This was to meet the ever-evolving agricultural industry demands. In response to the dynamic challenges faced by the agricultural industry, the organization began its journey into lean manufacturing. As part of its commitment to improving operational efficiency, reducing waste, and optimizing resource utilization, NMO-12 adopted the Lean Manufacturing principles. They laid the foundation for an agile and competitive operation by streamlining processes, improving workflow, and cultivating a Continuous Improvement Culture. The organization adopted Lean Six Sigma after success with Lean Manufacturing. By adopting this approach, their operations became more data-driven, defect-reduction-focused, and process-optimized and achieved consistent, high-quality outcomes.

## Case Organisation 13(MO-13)

With a legacy of remarkable growth and global influence, MO-13 in Colombo, Sri Lanka, is one of the most influential companies in the tire industry. Having established itself in the 1990s, this organization has grown into a global leader in the manufacture of industrial tires with a market share exceeding 25 percent. As an enduring example of innovation, excellence, and global impact, MO-13 has demonstrated an enduring spirit of excellence and innovation. It became Sri Lanka's largest foreign exchange provider. With the adoption of the Toyota Production System by MO-13 in early 2009, the company overcame the economic recession and, by 2012, the company had completely shifted to Lean Manufacturing Systems. A combination of Lean and Six Sigma was introduced in 2013.

## Case Organisation 14(NMO-14)

Among the leading telecommunications companies, NMO-14 has embarked on an LSS initiative that has set new standards for operational excellence and customer satisfaction, setting new standards for operational excellence. To drive continuous improvement and streamline operations, NMO-14 has leveraged the power of LSS to deliver top-tier services to its customers. By committing to LSS principles, NMO-14 has enhanced its business processes as well as created an environment that promotes efficiency and excellence among its employees. Through this journey, employees have been empowered to actively participate in process improvement initiatives, resulting in higher job satisfaction and a more fulfilling work environment as a result. NMO-14's journey towards LSS excellence highlights the tangible benefits achieved through LSS principles. This underscores its commitment to delivering exceptional services and driving operational efficiency in the dynamic telecommunications landscape.

## Case Organisation 15(MO-15)

MO-15 is a dynamic and innovative player in the textile and clothing industry, dedicated to enhancing its operations through LSS methodologies. With a strong commitment to quality and efficiency, MO-15 embarked on a transformative LSS journey that redefined its approach to textile manufacturing in 2008. As an industry leader MO-15 understands the importance of process optimization and continuous improvement. By leveraging Lean Six Sigma principles, the company has streamlined its manufacturing processes, reduced waste, and enhanced product quality. This dedication to excellence has translated into cost savings but also strengthened its position in the competitive textile market. Through its strategic approach to LSS and unwavering commitment to quality, MO-15 has solidified its reputation as a forward-thinking and responsible player in the textile industry. Its journey towards process excellence continues to drive innovation and positive change, setting the standard for textile manufacturing practices in the modern era.

## Case Organisation 16(NMO-16)

NMO-16, which is in Bangalore, has evolved into a comprehensive healthcare hub with a legacy dating back to the 1920s. NMO-16 offers 284 beds of the highest level of medical care. It is a super speciality tertiary healthcare provider with over 150 senior doctors and 800 paramedical professionals that provide super speciality care across 40 specialty areas, such as Cardiac Science, Neurology and Neurosurgery, Oncology, and more. In addition, the hospital has been certified by both NABH and JCI multiple times, and it is ranked among the top five medical tourism destinations in the world. To achieve continuous improvement, NMO-16 employs Lean Six Sigma methodologies to optimize healthcare processes and to strengthen its reputation as a global healthcare leader.

# Appendix – D: Online Survey

## Secondary/ Demographic Information

### 1. Individual Background

**Table D. 1 Survey items to assess the background of the respondents**

| |
|---|
| 1. What is your expertise level in LSS? |
| LSS Master Black Belt |
| LSS Black Belt |
| LSS Green Belt |
| Lean Practitioner |
| Continuous Improvement Expert |
| Other (Please Specify) |
| 2. How long have you been practicing LSS? |
| 0-1 year |
| 2-4 years |
| 5-9 year |
| More than 10 years |
| 3. What is your position in the organisation? |
| Text entry |
| 4. In what country are you currently working (mainly working)? |
| Please select the country from drop down list |
| 5. Select one from the three choices given below, to reflect your problem-solving approach for the project under review |
| Predominantly Lean |
| Predominantly Six Sigma |
| An approximately equal mix of Lean and Six Sigma |

## 2. Organisation Background

**Table D.1 Survey items to assess the background of the organisation**

| |
|---|
| 6. Which industry sector does your current organisation belong to? |
| Please select the industry (from drop down list) |
| 7. How would you classify your industry (Manufacturing or Service)? |
| Manufacturing |
| Service |
| Other (Please Specify) |
| 8. How many staff (full time equivalent) does your organisation employ? |
| Less than 250 |
| Between 251 and 500 |
| Between 501 and 1000 |
| More than 1000 |
| 9. Other than Lean and Six Sigma, what other continuous improvement methodologies has your organisation adopted (select all that apply)? |
| Total Quality Management (TQM) |
| Kaizen |
| Business Process Re-engineering (BPR) |
| Theory of Constraints (TOC) |
| Business Process Management (BPM) |
| Other (please specify) |
| 10. How long has your organisation been implementing LSS? |
| Less than 1 year |
| 1-4 years |
| 5-10 years |
| More than 10 years |

## 3. Selected Project Background

**Table D.2 Survey items to assess the background of the LSS Project**

| | |
|---|---|
| Consider the most recent LSS project you were involved with and answer all the questions below accordingly. | |
| 11. How would you classify the type of Lean Six Sigma deployment in the project? | |
| The project was following Define-Measure-Analyse-Improve-Control (DMAIC) using advanced Lean Six Sigma statistical tools | |
| The project was following DMAIC using simpler statistical tools with some lean tools | |
| The project used lean based tools with some simple quality tools | |
| The project methodology was derived from previous improvement initiatives such as Total Quality Management (TQM) and Business Process Reengineering (BPR) | |
| Other (please specify) | |
| 12. What was your role in this LSS project? | |
| Champion | Core team member |
| Sponsor | Extended team member |
| Master Black Belt | No Specific LSS position |
| Black Belt | External consultant |
| Green Belt | Other (please specify) |
| 13. What was the duration of the project to the nearest number of months and weeks? | |
| Months = | |
| Weeks = | |

## Measurement Related Survey Items

**Table D.3 Survey Items for each construct**

| | |
|---|---|
| Leadership Engagement<br><br>14. Please rate the following statements based on your recent LSS project experience | |
| LEN1 | Leadership was able to communicate effectively throughout the project with a solid communication plan. |
| LEN2 | Leadership created a learning environment. |
| LEN3 | Leadership empowered team members to accomplish goals and objectives throughout the project. |
| LEN4 | Leadership actively participated in reviewing and evaluating the project performance. |
| Continuous Improvement Culture<br><br>15. Please rate the following statements based on your recent LSS project experience | |
| CICUL1 | The organization promotes routinization, formalization, and structure. |
| CICUL2 | The organization places a strong emphasis on task focus, accomplishment, and goal achievement. |
| CICUL3 | The organisation assesses employee concerns and ideas. |
| CICUL4 | The organisation empowers employees to act. |
| CICUL5 | The organization employs creative problem-solving methods. |
| CICUL6 | The organization is committed to developing its personnel and expanding its knowledge to achieve its goals. |
| CICUL7 | Human relations, teamwork, and cohesion are important to the organization. |
| CICUL8 | The organisation encourages Participation, and open discussion. |
| CICUL9 | The organization focuses on innovation and change. |
| CICUL10 | Decentralization and flexibility are key components of the organization. |
| CICUL11 | Organizational objectives, goals, and directions are clearly defined. |
| CICUL12 | The organization is focused on ensuring continuity, stability, and order. |
| CICUL13 | The Organizations focus on predictable performance outcomes. |
| LSS Project Initiation | |

| | |
|---|---|
| 16. Please rate the following statements based on your recent LSS project experience | |
| PRIN1 | The initial stage of the project involved identifying the gap and its impact on the business. |
| PRIN2 | The team utilized a well-defined project selection strategy. |
| PRIN3 | The project had a well-defined scope |
| PRIN4 | The improvement resulting from the intervention had a well-defined scientific basis. |
| PRIN5 | LSS project objectives were aligned with business objectives during the initiation phase (Safety, Quality, Costs, Delivery, etc.). |
| PRIN6 | LSS project initiation included developing a clear execution plan, roles, responsibilities, and methods of communication. |
| LSS Project Execution (PREX)<br><br>17. Please rate the following statements based on your recent LSS project experience | |
| PREX1 | There was regular communication with the team and stakeholders regarding project needs and reporting status. |
| PREX2 | A robust risk management strategy was implemented to reduce risks and uncertainties during the execution phase. |
| PREX3 | LSS project execution began with a review of customer requirements, CTQs and a mapping of the project deliverables. |
| PREX4 | Project performance was measured using key performance indicators (KPIs) during the execution. |
| PREX5 | Dedicated time and resources were available to build a cohesive team. |
| PREX6 | Utilized innovative technology to tackle technical challenges during execution. |
| PREX7 | Implemented tools and processes to facilitate change |
| PREX8 | Tools and processes were implemented to ensure the quality of deliverables. |
| LSS Performance (LSSPER)<br><br>19. Please rate the following statements based on your recent LSS project experience | |
| LSSPER1 | The LSS project resulted in a reduction in defects and rework. |

| | |
|---|---|
| LSSPER2 | The LSS project resulted in improved delivery of products or services. |
| LSSPER3 | The number of customer complaints decreased after the implementation of the LSS project. |
| LSSPER4 | The LSS project reduced our organization’s waste while being socially responsible. |
| LSSPER5 | The LSS project resulted in improved cost savings. |
| LSSPER6 | The LSS project achieved its expected quality improvement targets. |
| LSSPER7 | The LSS Project related stakeholders were satisfied with the project results. |
| Project Residual Risk (PRRISK)<br><br>18. Please rate the following statements based on your recent LSS project experience | |
| PRRISK1 | The project team were unable to anticipate technology needs. |
| PRRISK2 | Due to the interdependence of project tasks, it was difficult for the team to assess the project needs. |
| PRRISK3 | It was difficult for the project team to obtain approvals due to the organization’s hierarchical structure. |
| PRRISK4 | The project team found it difficult to assess the expectations of external stakeholders due to regulatory changes. |
| PRRISK5 | Due to uncertainties in the external environment, the team was unable to predict business, social and environmental impacts (e.g., politics, economics, the law, and natural conditions). |

# Appendix – E: Comparison of Measurement Models and Structural Models for Manufacturing on Nonmanufacturing Firms

As part of this study, three stages were used to evaluate measurement models, structural models, and multigroup analysis (MGA) with the objective of exploring the alignment of Lean Six Sigma (LSS) with various sectors such as manufacturing and nonmanufacturing, along with comparing the estimated path coefficients. Similarly, to the analysis of the complete model described in chapter seven sections 7.6 and 7.7, the measurement model and structural model for both groups (manufacturing and nonmanufacturing) were assessed separately. By conducting MGA, the researcher aims to determine if the connections between factors and quality performance, as depicted in the final model, differ between these two sectors. It is possible to overlook the fact that the relationship identified in one group may not hold true for another group if comparing model assessments without considering potential differences across groups. A multigroup analysis will make findings more generalizable and applicable to a wider range of populations.

## Measurement Model Comparison

The assessment of the measurement model encompassed an analysis of manufacturing and nonmanufacturing data, separately for reflective and formative variables similar to the complete model assessment. The initial focus was on evaluating the reliability of the measurement scales associated with reflective constructs including Leadership Engagement, CI Culture, LSS Project Initiation, Project-Related Residual Risks, and LSS Project Performance.

## Measurement Model Assessment -Reflective Constructs

In accordance with the measurement model analysis of the complete model following the criteria proposed by Hair et al. (2022), the researcher evaluated the reflective constructs by examining the loadings of indicators alongside their respective constructs within both groups. The loadings exceeding the threshold of 0.708 were considered indicative of acceptable reliability. However, for both Manufacturing (M) and Nonmanufacturing (N-M) groups, some loadings fell short of this threshold. Items were retained or removed based on the need to improve critical reliability and convergent validity. As the AVE for LSS project initiation in the Manufacturing model was below the threshold (0.5), PRIN1 was removed from both models for comparison purposes. The findings presented in Table E.1 provide evidence of internal consistency within constructs for both groups.

**Table E.1 Measurement model analysis for both Manufacturing and Nonmanufacturing data**

| Construct | Item Code | Loadings | | Cronbach's alpha | | Composite reliability (rho_c) | | Average variance extracted (AVE) | |
|---|---|---|---|---|---|---|---|---|---|
| | | M | N-M | M | N-M | M | N-M | M | N-M |
| Leadership Engagement | LE1 | 0.852 | 0.838 | 0.844 | 0.874 | 0.895 | 0.913 | 0.681 | 0.725 |
| | LE2 | 0.801 | 0.838 | | | | | | |
| | LE3 | 0.793 | 0.879 | | | | | | |
| | LE4 | 0.854 | 0.851 | | | | | | |
| CI Culture | CUL1 | 0.661 | 0.525 | 0.936 | 0.931 | 0.944 | 0.940 | 0.551 | 0.531 |
| | CUL2 | 0.672 | 0.679 | | | | | | |
| | CUL3 | 0.813 | 0.804 | | | | | | |
| | CUL4 | 0.825 | 0.808 | | | | | | |
| | CUL5 | 0.800 | 0.827 | | | | | | |
| | CUL6 | 0.827 | 0.657 | | | | | | |
| | CUL7 | 0.819 | 0.682 | | | | | | |
| | CUL8 | 0.837 | 0.741 | | | | | | |
| | CUL9 | 0.598 | 0.710 | | | | | | |
| | CUL10 | 0.676 | 0.707 | | | | | | |
| | CUL11 | 0.624 | 0.685 | | | | | | |
| | CUL12 | 0.737 | 0.776 | | | | | | |
| | CUL13 | 0.739 | 0.757 | | | | | | |
| | CUL14 | 0.704 | 0.789 | | | | | | |
| LSS Project Initiation | PRIN2 | 0.740 | 0.752 | 0.703 | 0.815 | 0.817 | 0.870 | 0.528 | 0.597 |
| | PRIN4 | 0.677 | 0.780 | | | | | | |
| | PRIN5 | 0.734 | 0.728 | | | | | | |
| | PRIN6 | 0.718 | 0.787 | | | | | | |
| LSS Project Performance | LSSPER1 | 0.815 | 0.562 | 0.883 | 0.845 | 0.908 | 0.855 | 0.587 | 0.522 |
| | LSSPER2 | 0.750 | 0.707 | | | | | | |
| | LSSPER3 | 0.678 | 0.662 | | | | | | |
| | LSSPER4 | 0.756 | 0.709 | | | | | | |
| | LSSPER6 | 0.771 | 0.786 | | | | | | |
| | LSSPER7 | 0.829 | 0.800 | | | | | | |
| | LSSPER8 | 0.754 | 0.798 | | | | | | |
| Project Residual Risks | PRRISK1 | 0.721 | 0.731 | 0.816 | 0.838 | 0.865 | 0.880 | 0.563 | 0.595 |
| | PRRISK2 | 0.783 | 0.813 | | | | | | |
| | PRRISK3 | 0.826 | 0.790 | | | | | | |
| | PRRISK4 | 0.790 | 0.817 | | | | | | |
| | PRRISK5 | 0.615 | 0.700 | | | | | | |

***Note:*** M-Manufacturing and N-M represents the values for nonmanufacturing data

For both the Manufacturing (see Table E.2) and nonmanufacturing (see Table E.3) groups, the HTMT results indicate a satisfactory level of discriminant validity. With this measurement, a heterotrait–monotrait correlation ratio is calculated, and discriminant validity occurs when values are below 0.90, while a more demanding criterion is set below 0.85 (Hair et al., 2019). For both groups, this value is not exceeded by all the latent variables estimated in Mode A included in the model, thus concluding that the study's measurements are dependable and have sufficient convergent and discriminant validity.

**Table E.2 HTMT results for Manufacturing group**

| | CI Culture | LSS Project Initiation | LSS Project Performance | Leadership Engagement | Project Residual Risks |
|---|---|---|---|---|---|
| CI Culture | | | | | |
| LSS Project Initiation | 0.652 | | | | |
| LSS Project Performance | 0.420 | 0.562 | | | |
| Leadership Engagement | 0.718 | 0.684 | 0.359 | | |
| Project Residual Risks | 0.286 | 0.231 | 0.279 | 0.183 | |
| Project Residual Risks x LSS Project Execution | 0.201 | 0.031 | 0.085 | 0.180 | 0.176 |

**Table E.3 HTMT results for nonmanufacturing group**

| | CI Culture | LSS Project Initiation | LSS Project Performance | Leadership Engagement | Project Residual Risks |
|---|---|---|---|---|---|
| CI Culture | | | | | |
| LSS Project Initiation | 0.520 | | | | |
| LSS Project Performance | 0.350 | 0.601 | | | |
| Leadership Engagement | 0.635 | 0.339 | 0.317 | | |
| Project Residual Risks | 0.291 | 0.157 | 0.299 | 0.151 | |
| Project Residual Risks x LSS Project Execution | 0.155 | 0.050 | 0.097 | 0.078 | 0.429 |

## Measurement Model Assessment -Formative Constructs

To conclude the assessment of the measurement model, the validity of the LSS Project execution which is a formative construct was evaluated for the collinearity of its indicators. The variance inflation factor (VIF) and the significance level of the weights were examined for this purpose (See Table E.4). It can be concluded that there are no collinearity issues in both groups in this case since VIF levels are below the established limit (VIF <5, values of 5 or above are indicative of severe collinearity issues).

**Table E.4 VIF results for both Manufacturing and nonmanufacturing data.**

| Path | VIF | |
|---|---|---|
| | M | N-M |
| CI Culture -> LSS Project Execution | 1.902 | 1.733 |
| CI Culture -> LSS Project Initiation | 1.735 | 1.503 |
| LSS Project Execution -> LSS Project Performance | 1.146 | 1.057 |
| LSS Project Initiation -> LSS Project Execution | 1.535 | 1.259 |
| Leadership Engagement -> CI Culture | 1.000 | 1.000 |
| Leadership Engagement -> LSS Project Execution | 1.893 | 1.505 |
| Leadership Engagement -> LSS Project Initiation | 1.735 | 1.503 |
| Project Residual Risks -> LSS Project Performance | 1.114 | 1.263 |
| Project Residual Risks x LSS Project Execution -> LSS Project Performance | 1.099 | 1.210 |

## Structural Model Comparison

A summary of hypothesis testing results is presented in Table E.5 for the manufacturing and nonmanufacturing sectors. It assesses statistical significance and effect sizes, as well as empirical findings on the relationships between various constructs. LSS Project Initiation (PRIN) and Leadership Engagement (LE) are related. In the manufacturing group, the path coefficient (β) was 0.321 with a highly significant p-value of $< 0.001$ and Cohen's f2 indicated a low effect size of 0.09 in in the manufacturing context. Consequently, Hypothesis H1 was not supported for the nonmanufacturing group considering the path coefficient, p-value, and *Cohen's* $f^2$. Leadership Engagement (LE) and CI Culture (CICUL) were examined as part of hypothesis H2. In both manufacturing and nonmanufacturing groups, the path coefficients (path coefficients of > 0.5) and Cohen's $f^2$ were greater than 0.5 (indicating a larger effect), providing robust evidence for Hypothesis H2 within nonmanufacturing contexts. Overall, both manufacturing and nonmanufacturing groups consistently supported some hypotheses. Hypotheses H4, H5, and H8a demonstrated consistent relationships between both sectors using these two sectors as an example. The study, however, found that some hypotheses were supported in one group but not in the other, emphasising the importance of taking context into account.

To conclude, the Table E.5 presents a comprehensive description of the hypothesis testing outcomes, allowing for a better understanding of the relationships between constructs in various contexts. Considering the differing levels of support, the relationship under investigation is complex, and it is critical to consider sector-specific nuances when interpreting the results.

**Table E.5 Structural model of both Manufacturing and Nonmanufacturing data.**

| Hypothesis | Manufacturing | | | Decision | Nonmanufacturing | | | Decision |
|---|---|---|---|---|---|---|---|---|
| | Path coefficient (β) | p-values | Cohen's $f^2$ (Local) | | Path coefficient (β) | p-values | Cohen's $f^2$ (Local) | |
| H1: LE→PRIN | 0.321 | < 0.001 | 0.09 | Supported | 0.042 | 0.371 | 0.00 | Not Supported |
| H2: LE→CICUL | 0.651 | < 0.001 | 0.74 | Supported | 0.578 | < 0.001 | 0.50 | Supported |
| H3: LE→PREX | -0.001 | 0.001 | 0.00 | Supported | 0.088 | 0.252 | 0.01 | Not Supported |
| H4: PRIN→PREX | 0.492 | < 0.001 | 0.34 | Supported | 0.617 | < 0.001 | 0.68 | Supported |
| H5: CICUL→PRIN | 0.329 | <0.001 | 0.10 | Supported | 0.428 | < 0.001 | 0.15 | Supported |
| H6: CICUL→PREX | 0.334 | 0.051 | 0.13 | Supported | 0.164 | 0.108 | 0.04 | Not Supported |
| H7: PREX→LSSPER | 0.446 | 0.025 | 0.23 | Not Supported | 0.678 | < 0.001 | 0.92 | Supported |
| H8a: PRRISK→LSSPER | 0.157 | 0.001 | 0.03 | Supported | 0.158 | 0.027 | 0.04 | Supported |
| H8b: PRRISK*PREX→LSSPPER | 0.021 | 0.311 | 0.00 | Not Supported | -0.041 | 0.345 | 0.00 | Not Supported |

## Appendix – F: Publications Related to the Thesis

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| Name/title of Primary Supervisor: | Dr Nihal Jayamaha |
| In which chapter is the manuscript /published work: Chapter Five | |

Please select one of the following three options:

(●) The manuscript/published work is published or in press

- Please provide the full reference of the Research Output:

Perera, A. D., Jayamaha, N., Grigg, N. P., & Tunnicliffe, M. (2021). Lean six sigma through an Australasian lens: project definition, structure and practices. International Journal of Lean Six Sigma. https://doi.org/10.1108/ijlss-07-2021-0132

( ) The manuscript is currently under review for publication – please indicate:

- The name of the journal:

- The percentage of the manuscript/published work that was contributed by the candidate: 85%

- Describe the contribution that the candidate has made to the manuscript/published work:

All of the elements of the paper, from the introduction to the conclusion, are the candidate's sole contribution. Co-authors (Supervisors) have played an active role in developing the draft of the paper, and in tidying it up at the end.

( ) It is intended that the manuscript will be published, but it has not yet been submitted to a journal

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- Please provide the full reference of the Research Output:

Perera, A. D., Jayamaha, N. P., Grigg, N. P., Tunnicliffe, M., & Singh, A. (2021b). The Application of Machine Learning to Consolidate Critical Success Factors of Lean Six Sigma. IEEE Access, 9, 112411-112424. https://doi.org/10.1109/ACCESS.2021.3103931

( ) The manuscript is currently under review for publication – please indicate:

- The name of the journal: IEEE Access
- The percentage of the manuscript/published work that was contributed by the candidate: 90%
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In this paper, the candidate developed, collected, and tested a machine learning model, and devised a method for classifying CSFs. Co-authors (Supervisors) played an active role in drafting the paper. Dr A.Singh should be acknowledged for his review of the machine learning model used in this paper.

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Perera, A. D., Jayamaha, N. P., Grigg, N. P. and Tunnicliffe, M. (2019), "Theorising and testing the underpinnings of Lean Six Sigma ", Paper presented at 17 ANZAM (Australian & New Zealand Academy of Management Operations),University of Melbourne, Australia.

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