

Article

An Investigation into Lean Implementation Preparedness in the Engineering Projects Sector

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Abstract: Lean methodologies, a system widely used in the manufacturing industry, have demonstrated numerous benefits and added significant value to the industry. In the same way that other industries have benefitted from the application of Lean techniques, the engineering projects sector can also realise significant improvements by integrating Lean principles into its processes and operations. The study aims to gain a comprehensive insight into the application of the Lean concept, with a focus on the South African engineering projects sector. The findings of a thorough literature review, focussing on Lean techniques, technology, and the projects sector, examined key variables that have an impact on the effective implementation of Lean methodologies within this industry. The variables studied are skills and expertise, active work methods, and leadership style. The study also explores the impact of digital technologies on Lean implementation, exploring how these technologies enhance the integration of Lean practices. The study includes descriptive statistical analysis, exploratory factor analysis, and a confirmatory factor analysis of the data. A significant relationship is found between variables influencing Lean implementation and the effectiveness of Lean practices within the South African engineering projects sector.

Keywords: lean engineering; factor analysis; variables; project sector



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1. Introduction

Lean manufacturing is a concept in which processes are optimised to maximise output. The technique is commonly used in the manufacturing industry. The main idea is to maximise output while using the least amount of input. Furthermore, the technique seeks to reduce waste in the manufacturing system [1]. A few examples of Lean techniques include 5S, Kaizen, Six Sigma, Poka-Yoke, Kanban, Just in Time, and Takt Time. Another technique is the Last Planner System (LPS), a key element when introducing Lean into a project-based environment. This system is designed to create an optimal work environment by holding team members accountable for ensuring that those executing tasks have the necessary supplies, equipment, and information. Research has demonstrated that LPS significantly enhances operational efficiency and overall performance, making it particularly effective for small and medium enterprises (SMEs) in the construction project sector [2]. Implementing LPS within project-based environments is a critical factor for achieving successful Lean adoption. Each technique presents a distinct notion of establishing a Lean operation. By implementing these techniques, manufacturing companies can achieve cost- and time-efficient targets [3]. Typically, a successful firm will conduct ongoing research on adopting specific Lean tools to suit its operations. The adoption of Lean manufacturing methodology is not only feasible but also highly beneficial within the South African engineering projects industry. Introducing Lean techniques in the engineering projects industry has the potential to yield significant benefits. The Lean methodology that introduces the concept of waste reduction [4] can be proven to optimise project budget and delivery. Introducing these

techniques is a step towards moving away from traditional methods. The engineering projects industry is very dynamic, and for this reason, the environment is very changeable. On the other hand, the factory environment is easier to control. Lean engineering projects can be achieved by combining various Lean tools. Projects must be examined individually, and the best Lean tools should be applied. Ideally, a project must be completed within a finite budget [5]. A schedule must be set, and meeting the customer's quality requirements is essential. This research aims to realise the application of Lean techniques in the engineering projects industry and capitalise on the concept's benefits. The South African project engineering industry faces significant challenges due to implementing unsystematic approaches and conventional systems. Engineering projects frequently exceed budget and schedule, resulting in financial losses and customer dissatisfaction. This study seeks to address these issues by investigating the implementation of Lean techniques and their potential benefits, aiming to provide a systematic approach that enhances project outcomes and performance.

The research question is, "What factors influence the effectiveness of Lean implementation in the project engineering environment, and how do digital technologies affect this relationship?" This question aims to identify the key factors that impact the implementation of Lean techniques and to assess the influence of digital technologies in shaping this relationship within the engineering project sector.

The research gap lies in addressing Lean effectiveness, specifically within the South African project engineering industry. Hence, the focus is on identifying key factors that impact Lean implementation and providing solutions to maximise its benefits. This study is unique in employing a model that demonstrates the link between independent factors and Lean effectiveness. It offers a novel and comprehensive understanding of the challenges and opportunities within the project engineering sector in South Africa, linking these insights directly to the effectiveness of Lean practices in this industry.

The following sections of the article will first review the literature on Lean techniques, technology, and Lean implementation, as well as the project sector. This will be followed by a detailed explanation of the methodology used to study Lean effectiveness, including the research design, data collection methods, and analysis procedures. Next, the article will present the results, highlighting key findings related to Lean implementation. The discussion section will interpret these findings and relate them to the existing literature. The conclusion provides recommendations for practitioners and future research, summarising how the insights gained can improve Lean practices in the industry.

2. Background

This section addresses three key aspects. The first part focusses on Lean techniques; the second explores the role of technology in Lean implementation; and the third examines their application within the project engineering sector. While Lean principles have been extensively studied and applied within the manufacturing industry, there is limited research on their direct implementation in the engineering projects sector.

The background provided here will outline the benefits of Lean in its traditional manufacturing context, exploring how these principles, when combined with modern technological advancements, can be adapted to enhance value in engineering projects. Firstly, a description of Lean in its purpose-developed environment, the manufacturing industry, is provided. This is followed by examining how these concepts can be extended to engineering projects. This foundational understanding then sets the stage for developing the subsequent conceptual model.

2.1. Lean Techniques

The manufacturing industry has adopted Lean tools and is known for showing improved productivity [6]. Countries such as China have proven competitive advantages [7]. Implementing Lean methods has demonstrated positive effects and has been shown to make processes more optimised and efficient, enhancing an organisation's overall produc-

tivity and profitability [8]. The idea behind Lean implementation in an organisation is to allow continuous opportunities for long-term development [9]. The Lean tools are seen to be successfully implemented in the manufacturing and maintenance environment [10].

Lean principles are widely used worldwide, and it has been found that many benefits are associated with implementing the Lean concept [10]. The industry must profit through the implementation of the Lean technique system. The system should not be limited to manufacturing but should benefit all sectors. The Lean idea is adaptable to any industry and should be used in all sectors to reap the benefits. There are various Lean techniques, all of which show benefits in their own way [11]. It is emphasised that to experience the full benefit of Lean principles, organisations must accept the new approach to working and thinking [12]. Research has indicated that organisations confront obstacles in conducting constant improvement initiatives to enhance production efficiency [13].

Many organisations implement Lean techniques to see continuous improvement, greatly benefiting a business [14]. It is still evident that several barriers are affecting the implementation of Lean techniques [12]. Research conducted in the manufacturing industry demonstrates the effectiveness of Lean transformation on organisational structure and behaviour. It also highlights Lean methodologies' efficacy and sheds light on the elements that influence transformation and implementation [15]. The elements of an effective Lean structure are illustrated in Figure 1 below [15].

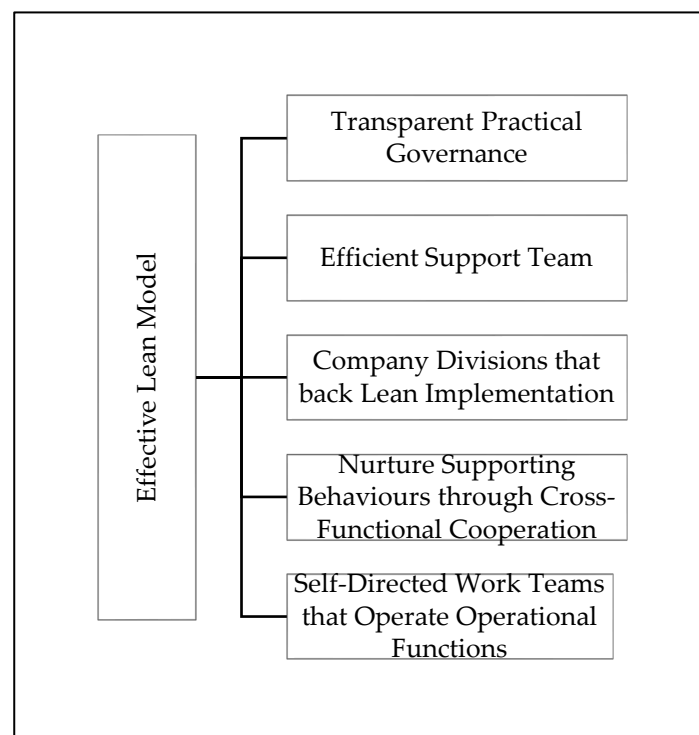


Figure 1. Effective Lean structure.

Organisations fail in the successful implementation of Lean techniques because companies are only engaged in the physical characteristics of Lean, which include Lean methods and principles [14]. A positive mindset and vision are also needed to implement Lean tools [2]. Additionally, top management teams must work to inspire staff members to uphold a continuous improvement and Lean principal culture [16]. Elements, such as the knowledge of key individuals and a lack of desire to make an innovative change, contribute to the difficulties encountered in applying Lean methodologies [17]. A company shift is required to apply Lean concepts because business culture plays a pivotal role in implementing Lean techniques [12]. With a fundamental change that has a significant impact, it is expected there will be strong resistance [12]. The behaviour of leaders plays a vital part in any organisational change [18]. Among the barriers affecting the implementation

of Lean techniques is the buy-in from employees and management [12]. Other factors that impact change are reluctance to make a change, low motivation levels of personnel, limited company goals, and poor conceptualisation of Lean tools [17]. At the same time, it is also emphasised that there is a need for training and knowledge transfer on Lean techniques before implementing them [11]. For Lean tools to be successfully implemented and show improvement in an organisation, it is necessary to incorporate the related human element that drives the Lean technique approach [6]. Businesses often find it problematic to establish a connection between adopting Lean methods and gains in operations [19]. The perception towards change plays a vital role in adopting Lean tools [11]. An organisation's success relies on its employees and performance [20]. Even though Lean manufacturing is widely acknowledged to enhance operations, many organisations are having trouble adjusting to the Lean mindset [20].

Lean principles have been extensively studied and adopted in various global industries, yet South Africa's adoption of these techniques has been relatively slow [21]. According to Donodofema et al. (2017), South Africa faces significant challenges in fully embracing Lean methodologies, which are already well integrated in countries like Germany [21]. The study highlights that despite having over 50 years of experience with Lean concepts, South Africa has not capitalised on this knowledge effectively. One of the critical gaps identified is the assumption by some South African companies that simply implementing Lean techniques makes them Lean. However, this overlooks the comprehensive nature of Lean, which requires more than just implementation. It demands a cultural shift and continuous improvement, deeply embedded within the organisation [21]. Furthermore, the study underscores the importance of human resources in driving continuous improvement, a core component of Lean. Continuous improvement, as highlighted, is not just a process but a culture that must be cultivated within the workforce. The failure to fully integrate these principles has prevented South African companies from realising the full benefits of Lean, such as increased efficiency, reduced waste, and enhanced competitiveness [21]. To bridge this gap, there is a need for targeted investment in Lean research and development, ensuring that Lean practices are implemented and sustained through continuous learning and improvement [21]. By addressing these gaps, South African industries, particularly in the engineering projects sector, can better align with global standards and leverage Lean methodologies to improve project outcomes. This is especially relevant in adopting new digital technologies, which can facilitate the implementation of Lean by streamlining processes and enhancing real-time decision-making [21]. Integrating Lean with digital technologies could be a significant step forward in achieving operational excellence in the South African engineering projects sector.

2.2. Technology and Lean Implementation

The increasing use of automation technologies in Lean manufacturing emphasises the need for a new phase of production system transformation [22]. This is enabled by Industry 4.0 technologies and aims to digitise production, improving industrial processes and systems. This allows quick adjustments in production methods to meet changing requirements, using innovative technology based on Industry 4.0 and Lean management principles [22]. Furthermore, looking at the construction project environment, Lean construction principles should be combined with digitalisation to improve efficiency and productivity in ongoing investment projects, commonly known as Lean 4.0 [23]. This combination enables a realistic strategy to increase worker productivity and project effectiveness [23]. However, before integrating digital technology into a Lean approach, it is recommended that the traditional physical Lean methodology be established [24]. This approach helps develop a culture of reflection and forward-thinking, setting the groundwork for innovation and preparing for digitalisation [24]. At the same time, it is worth noting that integrating Lean and Industry 4.0 poses challenges such as reduced flexibility, higher costs, and a limited ability to make changes during construction using Lean concepts.

The integration of modern technology has become indispensable across various disciplines, offering significant benefits in the engineering projects sector. Adopting new technologies extends to all sectors, providing crucial support for continuous improvement, an essential component of successfully implementing Lean methodologies [25]. The Industrial Revolution introduced groundbreaking ideas, concepts, and technologies, fundamentally transforming work processes [25]. Today, the implementation of strategies that facilitate ongoing improvement, in tandem with technological advancements, is vital for maintaining a competitive edge [25]. Also, the application of modern technology has proven to be beneficial in a variety of disciplines. The adoption of new technologies and the benefits thereof extend to all sectors [25].

In the context of Lean principles, new technologies complement and enhance Lean techniques, offering substantial benefits when integrated with appropriate processes [11,26]. Deploying multiple Lean tools alongside technology can streamline an organisation's operations, optimising system performance and operational efficiency. This symbiotic relationship underscores the importance of selecting the right technology, continuously improving its application, and staying abreast of technological advancements [27]. Implementing new technology creates opportunities to provide new solutions [28]. For example, Kriel (2020) discusses how technology can reduce labour requirements while simultaneously improving operational efficiency, which presents challenges and opportunities depending on the perspective [25]. Furthermore, it is understood that implementing digitalisation might lessen or eliminate present and upcoming difficulties in operational systems [27]. Effective management systems are critical to maximising the benefits of technology implementation. Organisations must recognise the significant advantages of adopting cutting-edge technology, ensuring that these innovations are aligned with Lean methodologies to achieve superior financial management and resource allocation [28]. The rapid adoption of new technologies in industries like packaging production demonstrates how technological advancements can create new opportunities and improve efficiency [28]. According to a case study conducted in the South African biomedical sector, technological improvement is a key strategy for process improvement, which extends beyond immediate operational gains to encompass broader organisational benefits [29].

Innovative technologies such as automation, AI, robotics, blockchain, and the Internet of Things are revolutionising the manufacturing sector [26]. These advancements facilitate better planning, scheduling, and execution of tasks with minimal disruptions, ensuring compliance with regulations and reducing the likelihood of human errors [26,30]. Mechanisation decreases the number of workers who engage with machines, decreasing the probability of human being mistakes and facilitating the speedier fulfilment of production objectives [30]. Studies show that digitalisation in asset management reduces or eliminates current and future challenges in system management [27], with research indicating that it leads to more effective system monitoring and problem resolution [11]. Innovative technology would allow for effective planning, scheduling, and execution of planned maintenance on time and with few disturbances, maintaining regulatory compliance [26]. Technology transfer is pivotal in maximising the benefits of technology adoption, particularly in emerging economies. According to Owusu-Manu et al. (2017), technology transfer fosters social infrastructure development and economic growth, as seen in Ghana's construction sector, where multinational companies serve as key innovation and technological improvement sources [31]. However, the success of technology transfer depends on regular evaluation and the effective transfer of knowledge and skills to local populations [31]. The need for ongoing assessment ensures that Indigenous people can acquire new knowledge and skills without difficulty, supporting the long-term benefits of technology implementation [31].

2.3. Lean Implementation in the Projects Sector

Implementing Lean techniques, particularly within the construction project environment, is an advanced approach to managing projects in this sector [10]. The benefits of implementing Lean techniques are evident, and it is widely recommended that these meth-

ods be adapted across various project sectors [7]. Evidence suggests that the South African construction project industry is actively exploring various Lean techniques, processes, and practices [10]. There are numerous Lean techniques, each with its own approach and method of implementation. These strategies will be applied differently in different project environments. It is important to note that while Lean concepts were originally established for the manufacturing sector, careful adaptation to suit the specific conditions of any other industry or project environment should lead to successful outcomes. The Lean approach involves different techniques, each contributing a unique perspective to a system or process. When implemented correctly, many benefits can be realised. The selection of a Lean tool depends on the specific project process and should involve matching the most appropriate tool to the given project needs [9]. Several Lean tools are available, and deploying one or more incorrectly can have negative impacts and add little value. Research indicates that the construction project sector is increasingly adopting Lean techniques [9]. Although Lean methods have only recently been adopted in project-focused construction environments, they were long associated with the manufacturing sector. In the South African construction space, Lean techniques are being applied to projects, with tools such as 5S and Kaizen identified to address issues like defects, overprocessing, waiting times, and underutilised staff skills [9]. A study on Lean audits has identified certain Lean features as standard across projects, including standardised work, housekeeping, swift changeover methods, total productive maintenance, and continuous improvement [19]. Moreover, it is emphasised that a mindset focused on continuous improvement is a critical component of the Lean philosophy within project management [19].

Over time, various strategies have been employed to enhance effectiveness and quality in the construction project sector [10]. Implementing Lean principles in construction projects aims to achieve task execution at a reduced cost, ensure client satisfaction, and minimise waste [10]. The prioritisation of safety and quality is vital for project execution and must be emphasised throughout the project lifecycle [2]. Research shows that SMEs in the construction project sector face numerous challenges [2]. Among these challenges are production inefficiencies, poor quality, overspending, and significant waste [2]. It is also important to recognise that Lean techniques are not a quick fix for problems; their benefits are only realised gradually over time [9]. However, consistent implementation of Lean techniques in projects is expected to lead to benefits such as financial improvement, quality enhancement, disciplined employees, and a highly skilled workforce [21]. In the context of construction SMEs, it is found that it is often best to implement tools requiring less cash investment [2]. However, the effectiveness of these strategies depends on a business structure that emphasises soft factors such as regard for people, shared values, transparency, trust, and teamwork [32]. Additionally, a study on sustainability in projects highlights that successfully integrating sustainable development dimensions at various phases of the construction project lifecycle requires a combination of project management competencies, including organising, leading, planning, and technical knowledge [33]. Furthermore, it has been established that the success and development of Lean methods in the projects industry, specifically construction projects, highlights the need to address barriers to broader adoption [34]. The key obstacles impacting the success and development of Lean methods, as identified by Al Balky et al. (2021), are as follows: lack of top management support, inadequate worker training, limited awareness of Lean principles, ineffective communication of necessary information, and insufficient stakeholder involvement and transparency [34].

Research in the structural design sector highlights the issue of waste and demonstrates how Lean practices can reduce this waste, bringing value to project outcomes [35]. The design process in engineering projects, particularly during the pilot and detailed design stages, often generates waste, negatively affecting project success [36]. Effective management strategies are essential to mitigate waste in the design phase, as they directly impact the overall efficiency and quality of project execution [36]. The design stage typically involves compiling client requirements, developing technical drawings, evaluating these

drawings for compliance, and executing the approved designs in the field [36]. Addressing waste at each stage is critical for enhancing project performance and ensuring the successful delivery of engineering projects [35,36]. The broader project sector in South Africa, including engineering and construction projects, involves substantial annual investments [10]. However, the sector still lags behind the manufacturing industry in adopting Lean techniques [10]. Given the significant financial stakes, funds must be allocated and utilised systematically to avoid waste and maximise the potential benefits of Lean methodologies [10]. Implementing Lean principles across projects is crucial for reducing waste and improving overall operational efficiency and project performance [2,10]. The systematic application of these principles can lead to more efficient use of resources, better alignment of project goals with client expectations, and reduced unnecessary expenditures, all of which are vital for successful project outcomes [2]. Lean principles in the project sector aim to enhance productivity, reduce execution time, and improve safety and quality throughout the project lifecycle [2]. These benefits are particularly important in sectors where project timelines are critical and client satisfaction is paramount [2,37]. Moreover, Lean techniques minimise waste and optimise resource utilisation, which are key factors in achieving project success [37]. While these principles offer significant advantages, it is essential to recognise that their benefits are realised gradually and require consistent application over time [9]. This approach is especially relevant for SMEs within the project sector, which often face challenges such as production inefficiencies, poor quality, overspending, and waste [2,9]. Addressing these issues through Lean methodologies can lead to significant operational improvements and long-term success [9]. Moreover, research has shown that Lean techniques positively impact reducing waste, improving quality, and increasing value for money across various projects [37]. It is often emphasised that the successful implementation of Lean principles requires the simultaneous application of multiple Lean tools, tailored to the specific needs of each project [21]. This multifaceted approach allows organisations to address their unique challenges, ultimately leading to better financial performance, higher-quality outputs, and more disciplined and skilled teams [21]. The benefits of Lean techniques are not confined to any single industry; they are applicable across various sectors, including engineering projects, where the focus is on enhancing efficiency and reducing waste throughout the project lifecycle [21,29]. By addressing common issues such as excess working capital tied up in stock and the need for rework, Lean methodologies help organisations streamline their operations, reduce costs, and improve overall project outcomes [29]. It has been shown that small and medium-sized firms (SMEs) play a key role in an economy [7]. Throughout a project's life cycle, various methods and processes are executed at different stages, each requiring separate management systems to ensure successful project outcomes [10]. Projects, particularly in the engineering and construction sectors, are unique and complex, often executed on-site, distinguishing them from the manufacturing sector [10]. This distinction necessitates a different approach to implementing Lean techniques originally developed for manufacturing [10]. Despite these challenges, it has been demonstrated that Lean tools can be effectively integrated into the project cycle, yielding significant benefits.

In recent years, the project sector has adapted Lean manufacturing tools to be more flexible, leading to the evolution of the term "Lean construction" [32]. Lean construction is a project delivery approach that focusses on meeting customer needs while simultaneously reducing waste [32]. Elements of the Lean construction culture, such as ensuring dependable workflow, fostering teamwork, respecting individuals, and enhancing transparency, were inherent in traditional construction practices [32]. However, it has been observed that while Lean approaches are utilised in project environments, they are not always formally adopted. Collaboration, standardisation, and sustainability are critical to implementing Lean principles within project sectors. Lean construction emphasises creating a collaborative environment, standardising products and processes to make projects more efficient, and ensuring sustainability, particularly in waste reduction and social and environmental responsibility [32]. Internationally, the sustainability of construction and engineering

projects poses a significant challenge, impacting various stakeholders, including developers, designers, and city planners [38]. Proper project planning is essential to address these challenges, and sectors like construction must explore multiple avenues to improve project efficiency and outcomes [39]. Research indicates that a Lean engineering strategy can save space and address issues like excessive waste generated during project execution [39]. Applying Lean techniques minimises waste and reduces the negative environmental impact of projects. For instance, a case study in the building construction sector found that clients' requests for more space are often met, but the space is not always optimised, leading to increased costs [39]. Government authorities also play a crucial role in promoting sustainable project practices, and collaboration with the private sector is encouraged to implement Lean techniques effectively [38]. Studies on Lean methodologies across various African countries highlight the mixed readiness of construction companies to adopt these practices. For example, research on Nigerian construction firms shows that while there is process readiness, there are significant gaps in technology, people, and management, indicating an overall unpreparedness for Lean construction [40]. The study emphasises the need for training and awareness, suggesting that tertiary institutions should offer programs related to Lean techniques [40]. Despite the challenges, the construction industry remains a major source of employment globally, though persistent issues continue to affect the sector [40]. While Lean techniques were initially developed for manufacturing, research shows they have been successfully applied in various project sectors. The adoption approach may vary depending on the industry and the specific organisation, but the benefits of Lean methodologies have been significant across multiple sectors. There is also evidence that some sectors implement Lean concepts indirectly without formally recognising them as such. The advantages of Lean principles, well-documented in manufacturing, have been shown to offer substantial value to other industries. However, adoption rates remain relatively low outside of manufacturing on a global scale.

3. Materials and Methods

3.1. Conceptual Model and Hypothesis

The South African engineering projects industry, spanning sectors such as mining, oil and gas, renewables, power, and the built environment, faces numerous challenges that impede project efficiency and success. These challenges have prompted a growing interest in the strategic implementation of Lean principles. These methodologies were originally developed for the manufacturing sector but are now being adapted to meet the specific needs of engineering projects. This adaptation is a critical step towards improving project performance, reducing waste, and enhancing overall efficiency [7,36]. In addition to Lean practices, the integration of modern technology is becoming increasingly recognised as a pivotal factor in driving Lean effectiveness within the engineering projects sector. Digital tools and advanced technologies have shown promise in streamlining project processes, enabling real-time data analysis, and fostering better decision-making throughout the project lifecycle. This technological focus aligns with broader industry trends, emphasising innovation and continuous improvement as key drivers of project success [25]. The literature highlights that the effective combination of Lean principles and technology can significantly improve quality, cost reduction, and project delivery times. By leveraging these tools, the engineering projects sector can achieve outcomes similar to those observed in the manufacturing industry, where Lean practices have led to substantial improvements in efficiency and productivity [2,10].

The conceptual model developed in this research addresses a critical gap by assessing the factors that influence Lean effectiveness within the South African engineering projects sector. This model identifies key independent and dependent variables related to Lean implementation. The study aims to provide actionable insights to enhance Lean effectiveness and project outcomes across the engineering projects industry through this comprehensive framework. Figure 2 below illustrates the conceptual model, detailing the independent

and dependent variables and their relationships. The following paragraphs will provide a detailed explanation of each variable within the model and their respective roles.

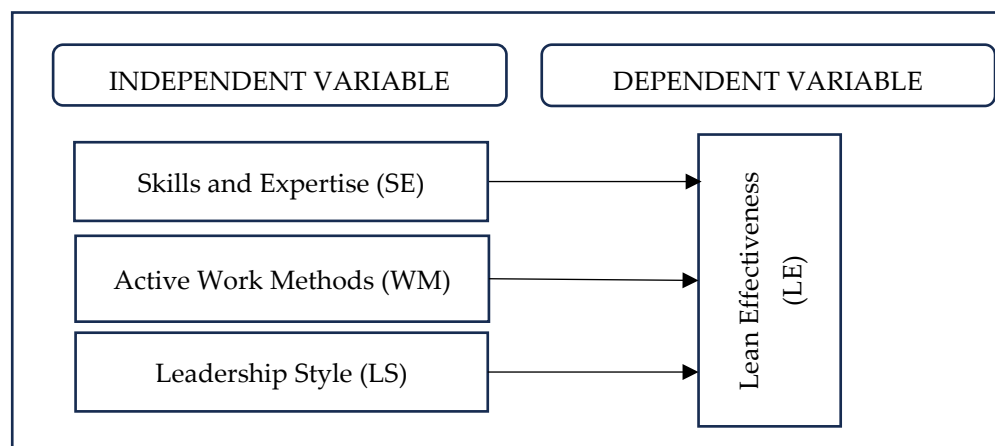


Figure 2. Conceptual model.

3.1.1. Skills and Expertise

Possessing skills and expertise is necessary for engineering projects to successfully implement Lean techniques [17]. The effectiveness of these techniques hinges on having qualified personnel [21] who can competently operate both traditional Lean methodologies and modern digital technologies. In engineering projects, the correct application of machinery and equipment by skilled individuals ensures high-quality and consistent output. Inexperienced personnel can lead to errors, increased rework, and wasted resources, which detract from the efficiency and effectiveness of Lean practices. Digital technologies like advanced project management software, data analytics, and automation tools require specialised knowledge and skills. Competent personnel adept in both Lean techniques and digital tools can facilitate smoother task transitions and enhance overall project performance [27]. Ensuring that a company has the right mix of skills supports efficient task execution [20]. Thus, a capable team is essential for effectively implementing Lean engineering techniques and achieving optimal project outcomes.

3.1.2. Active Work Methods

Effective implementation of Lean engineering requires robust active work methods within a company. To ensure Lean techniques are successful, tasks must be completed correctly the first time to minimise rework [10]. This involves having processes and safeguards in place to detect and correct errors early, preventing costly mistakes, and ensuring consistent quality [21]. Proper documentation of processes and procedures is critical, ensuring that tasks are performed correctly and efficiently. In engineering projects, this includes the systematic maintenance of equipment, which is vital for project execution. Reliable equipment is essential for maintaining project timelines and quality standards. Regular audits help verify that systems function correctly and standards are upheld. Additionally, integrating digital technologies can enhance these active work methods by providing real-time data and analytics to streamline operations further [26]. Thus, adopting effective active work methods and leveraging digital tools are crucial for successfully implementing Lean engineering practices in the engineering projects sector.

3.1.3. Leadership Style

An organisation's leadership style is crucial in successfully implementing Lean engineering techniques [18], particularly in the project engineering sector, where complexity and precision are key. Leaders must create a work environment that aligns with Lean principles, ensuring that employees are not overworked, which can lead to burnout and diminished productivity. In today's digital age, leveraging digital technologies is essential

for enhancing communication, streamlining workflows, and minimising inefficiencies [25]. High-quality management reduces waste, increases production, and keeps costs low [41]. Effective leaders use these tools to maintain regular and transparent communication with project teams, enabling them to address challenges swiftly and provide necessary support. Leaders should be present on project sites using digital tools for real-time monitoring and feedback. This dual approach allows leaders to identify wasteful activities and inefficiencies while ensuring that Lean principles are correctly applied. Moreover, prioritising employee well-being and encouraging continuous improvement are critical aspects of a leadership style that supports Lean implementation [16]. By integrating digital technologies with strong leadership practices, organisations in the project engineering sector can maximise the benefits of Lean techniques, resulting in more efficient project execution and improved overall outcomes.

3.2. Research Design

Various research papers, articles, journals, books, conference papers, and other research works are reviewed to thoroughly understand the issue and uncover literature gaps. The literature is compiled, and an analysis is performed to identify the relevant study variables. The literature review focusses on existing research and academic works on Lean manufacturing and the effectiveness of its implementation in the South African engineering projects industry. There is, however, a lack of literature covering the engineering projects industry in the South African setting. The literature evaluation explores the extraordinary obstacles confronting the South African engineering projects sector, such as insufficient project management, labour productivity concerns, and restricted resource availability. The study examines how managers can encourage Lean methodologies and cultivate a workplace environment that values ongoing development and progress. It also investigates South African engineering professionals' understanding and awareness of Lean techniques and ideas and the influence of collaborative relationships among project stakeholders on Lean implementation. The review identifies literature gaps and serves as a foundation for the questionnaire-based research, providing a valued understanding of the aspects influencing the successful application of Lean concepts and informing recommendations to improve the South African project engineering sector's approach to Lean adoption. The essential factors and research questions were defined before the questionnaire was developed. The questionnaire's objective is to collect data that will assist in answering these research questions and give insights into the South African engineering projects sector's effectiveness for Lean implementation. A questionnaire was created to address and examine each research issue thoroughly. The literature research findings, which identified different Lean effectiveness variables relevant to the project engineering sector, were used to develop the questionnaire. These criteria, collected from previous research and scholarly publications, were used to design specific questions for the questionnaire. The questionnaire's comprehensive nature, alignment with the research questions, and incorporation of relevant Lean effectiveness factors ensure that the data collected will provide valuable insights into the South African engineering projects sector's approach to Lean implementation. The questionnaire was used to collect empirical data, allowing for a complete examination of the study topic and contributing to the creation of significant results and suggestions for enhancing Lean effectiveness in the sector. A framework is developed for the research, and these steps are shown in Figure 3 below.

A 5-point Likert scale (strongly disagree, disagree, slightly agree, agree, and strongly agree) is used to gather information through the questionnaire. Multiple-choice questions are one type of closed-ended question, utilising a Likert scale and rating systems [42]. To quantify a complicated concept, researchers frequently use scales and indices [42]. The research is based on a qualitative, quantitative, and descriptive study. Participants are asked questions about key factors related to Lean techniques. These include skills and expertise, active work methods, and leadership style. Participants are asked questions related to these aspects so that data are available to analyse and understand the Lean effectiveness

in the project engineering sector. These aspects and the content of the questionnaire are addressed as follows:

1. Skills and Expertise

It is necessary to have the correct skills and expertise for the effective implementation of Lean techniques. This question addresses the level of skill and knowledge in the organisation to understand the calibre of personnel running the business and operation. These aspects are listed below.

- (SE1) Employees show a high-quality, steady output.
- (SE2) Machinery and equipment are correctly operated by competent personnel.
- (SE3) There is an overlap of skills that allows a smooth movement of tasks.
- (SE4) No re-work is required on projects.

2. Active Work Methods

These questions address the active work methods in the organisation. The statements revolve around the organisation's processes, procedures, and systems. For Lean effectiveness, a company is expected to believe that implementing processes, procedures, and systems positively impacts the organisation's success. The aspects of active work methods stated in the questionnaire are listed below.

- (WM1) The company has processes that ensure tasks are performed the first time correctly, avoiding rework.
- (WM2) Processes and procedures in the organisation are accurately documented.
- (WM3) Measures are in place to identify mistakes early enough, and these mistakes are corrected.
- (WM4) Systems are in place to ensure systematic maintenance of equipment.
- (WM5) Regular audits are performed to maintain systems and ensure uniformity.

3. Leadership Style

The right leadership style is needed for the effective implementation of Lean techniques. In this question, the organisation's leadership style is addressed, where the aspects discussed are the way top management does things in the organisation and the employee behaviour and pattern relating to leadership style. The factors addressed in this question are listed below.

- (LS1) Employees are not overworked.
- (LS2) Senior management often walks around the shop floor and project site to identify wasteful activities and inefficient processes.
- (LS3) Top management connects with the teams to understand how their work can be made more effective and more accessible.
- (LS4) Human resources are effectively managed, and no significant issues are experienced with personnel.
- (LS5) The employee resignation rate in the company is low.

4. Lean Effectiveness

The effectiveness of Lean implementation is dependent on various factors. In this question, the participant is expected to rate the Lean effectiveness. The question covers client satisfaction, professional execution of projects, and effective cost management. These aspects are listed below.

- (LE1) Clients are satisfied with the performance of projects.
- (LE2) Complex projects are executed professionally.
- (LE3) Cost management is of a high standard, and projects are delivered within budget.

The questionnaire was distributed to targeted participants within the South African engineering projects industry, specifically in the mining, oil and gas, renewables, power, and built environment sectors. Participants were selected from various departments across these industries. The research focused on companies in South Africa due to the identified

research gap within the South African engineering projects sector. After distribution, the collected data were statistically analysed to derive meaningful insights.

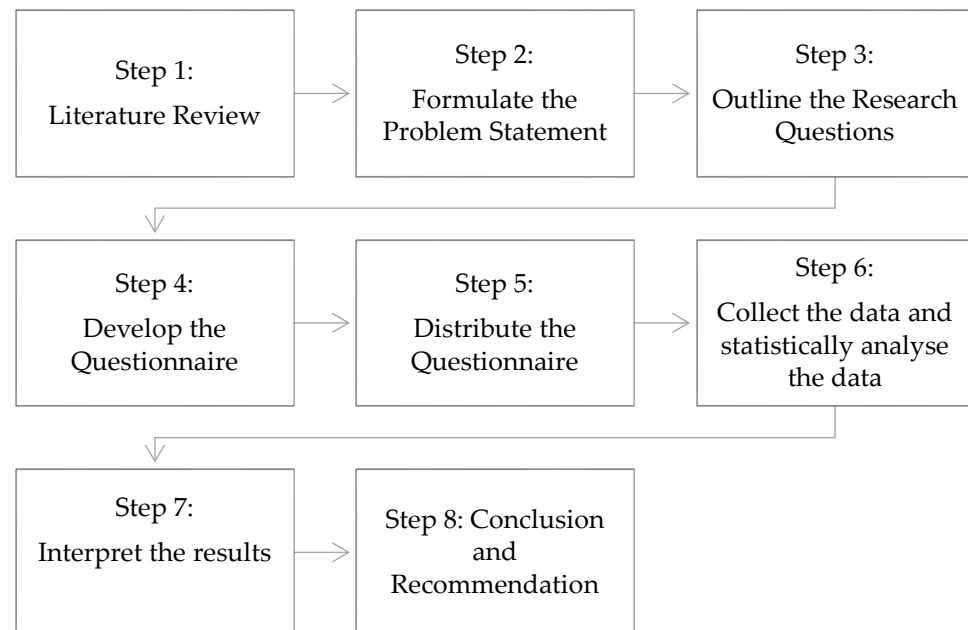


Figure 3. Research framework.

3.3. Data Collection and Statistical Analyses

The next phase in the study procedure is to collect and tabulate the data after receiving the completed questionnaires from the participants. This entails organising and arranging the replies methodically to allow for further analysis. Given the nature of the variables and research objectives, relevant statistical methods will be used to examine the data. A descriptive analysis of the company details is carried out. Descriptive quantitative analyses have to constantly be among the first steps in the data analysis process, regardless of the study topic or methodology [43]. The data analyses were performed using IBM SPSS version 29 and JASP version 0.18.3.0 (<https://jasp-stats.org>, accessed on 20 June 2024) statistics software. A reliability analysis is performed to test the consistency of the data. Reliability pertains to the consistency of the outcomes and how confident readers may be of the research's explicability [44]. Cronbach's alpha (α) is the most often used statistic for reliability [45]. An exploratory factor analysis and a confirmatory factor analysis are performed. Before conducting an exploratory factor analysis (EFA), two checks need to be carried out to assess the feasibility of the analysis [46]. These checks are Bartlett's test of sphericity and the Kaiser–Meyer–Olkin test of sampling adequacy (KMO). A chi-square test is performed to determine the model as part of the confirmatory factor analysis. The covariances are determined to understand the statistically significant relationship between individual factors and Lean effectiveness. This will provide a thorough knowledge of the elements driving Lean effectiveness in the South African engineering projects industry.

4. Results

4.1. Descriptive Analysis of Company Details

Using descriptive analysis, this part provides a thorough review of the company's data. Data should be displayed using a bar graph or pie chart, according to Peter M. Nardi, if the variable contains few discrete values, such as nominal or ordinal measures [42]. Tables are used in this section as an essential tool to show the data in a summarised and organised structure. A bar graph is a display tool that uses rectangular bars to offer a graphical representation of data and provide quantitative information about measurable attributes [47]. A circular graph known as a pie chart is used to display the size or propor-

tion of different categories. Each pie chart slice represents the percentage of data available in the category [47]. The study was limited to South African-based businesses, and the goal was to collect information from businesses in each of the nation's nine provinces. The number of responders from each province is displayed in Table 1 below.

Table 1. Number of respondents per province.

Province	Number of Respondents
Gauteng	37
Limpopo	3
Northwest	3
Mpumalanga	4
Orange Free State	0
Western Cape	15
Northern Cape	1
Eastern Cape	1
Kwazulu Natal	9
Total Number of Respondents	73

The graph below, Figure 4, shows the percentage response from each province relative to the total number of respondents.

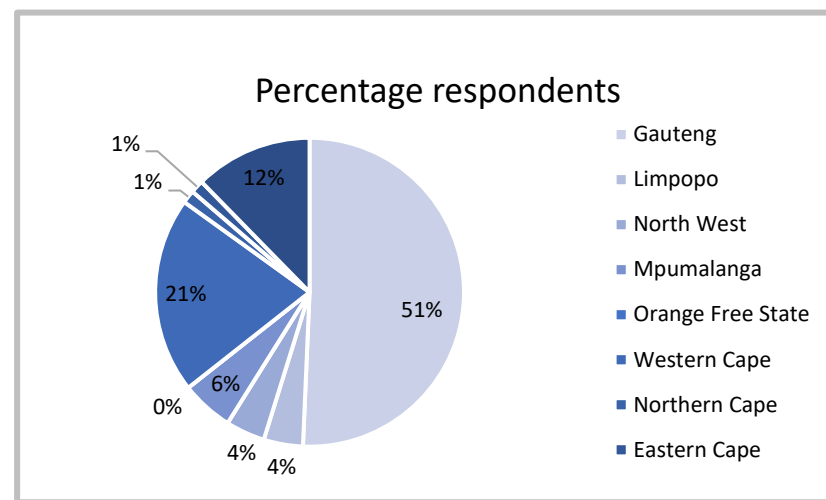


Figure 4. Pie chart showing respondents per province.

The analysis of participant distribution across the nine provinces in South Africa provides valuable insights into the regional engagement with the research and the concentration of efforts, particularly in Gauteng, where 51% of respondents hail from this province. Practical considerations drove the decision to focus distribution and follow-up efforts in Gauteng, as the researcher's presence in this province facilitated direct engagement, especially with those who met in person. The substantial response rate from Gauteng suggests the effectiveness of this strategy. In contrast, the Western Cape and KwaZulu Natal followed, accounting for 15% and 9% of the respondents, respectively. The variation in response rates across provinces underscores the geographical distinctions in participant engagement. The concentration of responses in certain regions, coupled with the acknowledgement of potential higher responses with additional resources for travel, raises questions about the sample's representativeness. The absence of responses from the Orange Free State is noteworthy and may prompt reflections on the outreach strategy or regional

dynamics. While the regional distribution of responses provides a snapshot of engagement, it is essential to recognise the limitations imposed by resource constraints. The higher response rates in provinces where direct engagement was feasible underscore the importance of considering practical factors in research design. The provincial analysis reveals a regional response imbalance, with Gauteng dominating due to strategic engagement efforts. The varying response rates across provinces add a layer of complexity, emphasising the need for cautious interpretation of regional findings.

For the research, people from specific departments were targeted, as it is expected that these people would understand the research subject matter best. A big focus has been on people from the operations and projects departments. This has also been extended to senior managers, owners, or consultants. Some companies may be small, have a small structure, or need a better structure. In these cases, we expected participation by the company's owner or senior management. The sample size for each department is displayed in Table 2 below.

Table 2. Number of respondents per department.

Department	Number of Respondents
Operations	20
Projects	29
Senior Management	8
Owner	4
Consultant	1
Projects and Operations	4
Operations and Senior Management	2
Projects and Senior Management	2
Other	3
Total Number of Respondents	73

The departmental distribution of participants within organisations sheds light on the targeted focus and subsequent engagement levels. The research strategically focused on specific departments, anticipating a heightened understanding of the research subject matter among individuals in these roles. A particular emphasis was placed on personnel from operations and projects departments and senior managers, owners, or consultants, recognising their pivotal roles in organisational functions. The outcomes reveal that 40% of the total respondents belong to the projects department, indicating significant engagement from this segment. The operations department closely follows, representing 27% of the respondents. The intentional targeting of these two departments aligns with the expectation that individuals in these roles would resonate best with the research questions, given their direct involvement in operational and project-related aspects. Moreover, senior management and owners collectively contribute 16% of the total respondents, signifying a noteworthy response from key organisational decision-makers. This diverse engagement across various hierarchical levels is crucial for capturing comprehensive perspectives and insights. Notably, 4% of respondents indicated functions spanning multiple departments, demonstrating the multifaceted roles individuals may play within an organization. Additionally, 4% originate from departments that are not explicitly specified, underscoring the fluidity of organisational structures. In essence, the departmental analysis attests to the targeted nature of participant selection, yielding substantial responses from departments intricately tied to the research objectives. This intentional focus has facilitated an exploration of perspectives from varied organisational functions, deepening the magnitude of the data collected.

4.2. Reliability Analysis

A Cronbach's alpha reliability analysis was conducted to assess the internal consistency of the questions within each factor. The results are shown in Table 3 below. Additionally, the overall Cronbach's alpha for the entire dataset was calculated to evaluate the consistency of the data, and the results are shown in Table 4 below.

Table 3. Reliability of factors.

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha If Item Deleted
SE1	54.4932	74.448	0.158	0.724
SE2	54.4110	72.745	0.209	0.720
SE3	54.5205	70.892	0.278	0.713
SE4	54.8767	73.304	0.262	0.713
WM1	54.2055	72.138	0.256	0.715
WM2	54.1507	68.296	0.438	0.696
WM3	54.2192	70.618	0.363	0.704
WM4	54.2329	70.764	0.307	0.709
WM5	54.1507	72.435	0.253	0.715
LS1	54.5890	69.495	0.351	0.705
LS2	54.0274	70.305	0.327	0.707
LS3	54.3699	71.347	0.310	0.709
LS4	54.2877	68.902	0.377	0.702
LS5	54.3014	71.880	0.302	0.710
LE1	54.2055	73.221	0.370	0.707
LE2	54.2466	71.994	0.324	0.708
LE3	54.3288	70.640	0.385	0.702

Table 4. Reliability of the overall dataset.

Cronbach's Alpha	No. of Items
0.7217	17

A Cronbach's alpha value ranging from 0.5 to 0.8 is deemed to have moderate reliability [45]. This implies that anything below 0.5 is low reliability, and anything above 0.8 is high reliability. The analysis shows that Cronbach's values range between 0.696 and 0.724. This range indicates a pretty good level of internal consistency. This further suggests that the items in the questionnaire show moderate reliability. The Cronbach alpha for the overall dataset is 0.7217. This suggests that the items in the questionnaire are relatively reliable. Calculating Cronbach's alpha has shown the overall reliability of the data. This data analysis will be complemented with other forms of analysis in this section.

4.3. Exploratory Factor Analysis

Bartlett's test of sphericity and the Kaiser–Meyer–Olkin test of sampling adequacy (KMO) were conducted on the variables. Bartlett's test of sphericity for the data indicates a significance of less than 0.001; hence, it is appropriate to perform a factor analysis [46]. The KMO value indicates whether it is worthwhile to conduct a factor analysis [46]. The KMO value of the data is 0.720, which is greater than 0.500, hence acceptable [46]. The eigenvalues are computed to assess the variance within the data. This distinction is demonstrated by a particular factor [46]. The eigenvalues are decreasing in value, which is expected. Factors 1

to 3 have eigenvalues greater than 1, explaining 58.152% of the variance. According to the Guttman–Kaiser rule, factors with eigenvalues greater than or equal to 1 are considered [46]. A scree plot that visually represents the eigenvalues. The scree plot, represented in Figure 5 below, offers a graphical overview of the eigenvalues for analysis and interpretation.

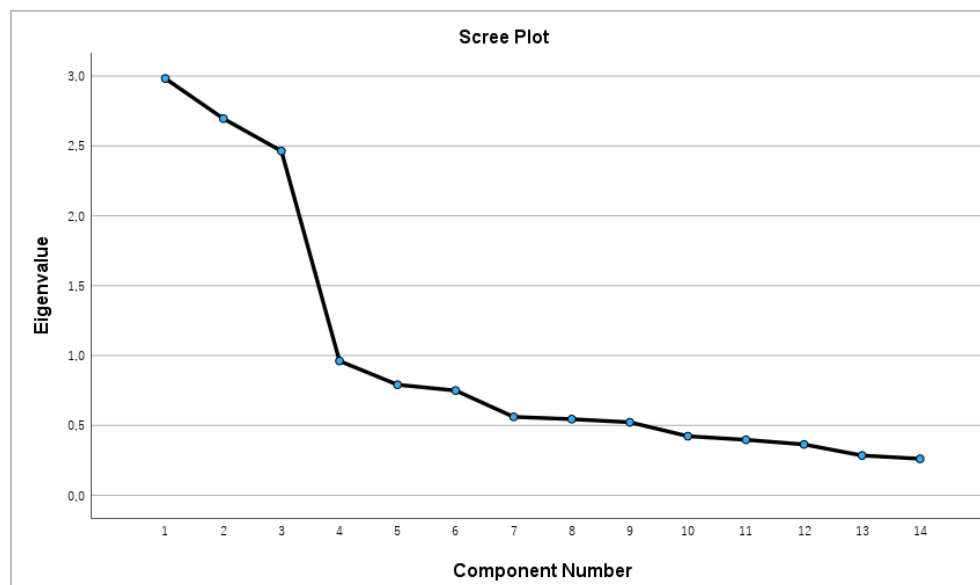


Figure 5. Scree plot showing the number of factors to retain based on eigenvalues.

The scree plot displays the eigenvalues of each factor and helps identify the optimal number of factors by showing where the eigenvalues begin to level off. To decide how many factors to retain from a scree plot, look for a significant drop in the eigenvalues, followed by a point where the decrease becomes gradual [46]. According to the scree plot analysis, after factor 3, there is a noticeable change in the slope of the plot, indicating an elbow point. This suggests that retaining three factors for further analysis based on the observed variance is appropriate without overfitting the model. Focussing on these three factors keeps the model simple, and meaningful data are retained.

Table 5 below displays the communalities of each item. The communalities for the dataset range from 0.351 to 0.724. For the common factor model to fit well for the items, the variables must have high communality [48]. This means that the variables should share a significant amount of variance with the common factors in the model. High communality indicates that the variables are well-represented by the common factors and are suitable for the common factor model. Table 6 below provides a rotated component matrix of the data. This matrix illustrates the factor loadings, representing the relationships between each specific factor and item within the dataset [46].

When determining the allocation of an item to a specific factor, a particular criterion is utilised. This criterion is defined by a threshold of 0.3, indicating the level of association required for an item to be linked with a factor [46]. Upon close examination of the matrix, it becomes apparent that each item is distinctly connected to a specific factor based on the established criterion. This process enables a clear and systematic approach to factor-item allocation within the matrix. Skills and expertise questions are related to factor 3. Active work methods are associated with factor 2, and leadership style questions are associated with factor 1. To ensure the reliability and validity of this allocation process, each item's factor loading was assessed in relation to the threshold. Factor loadings below 0.3 were deemed insufficient for clear association, while those meeting or exceeding the threshold were considered significant. This approach ensured that items with a strong correlation to a factor were accurately identified, contributing to a robust factor structure. The clarity of item-factor associations confirms that the factors identified reflect distinct and meaningful constructs within the study's framework. By adhering to this criterion,

we enhance the precision of factor analysis and provide a solid foundation for further interpretation and analysis.

Table 5. Communalities.

	Initial	Extraction
SE1	1.000	0.592
SE2	1.000	0.586
SE3	1.000	0.724
SE4	1.000	0.567
WM1	1.000	0.351
WM2	1.000	0.526
WM3	1.000	0.608
WM4	1.000	0.621
WM5	1.000	0.626
LS1	1.000	0.628
LS2	1.000	0.558
LS3	1.000	0.519
LS4	1.000	0.624
LS5	1.000	0.611
Extraction Method: Principal Component Analysis.		

Table 6. Component matrix.

	Component		
	1	2	3
SE1	−0.072	−0.283	0.712
SE2	−0.045	−0.292	0.706
SE3	−0.020	−0.178	0.832
SE4	0.043	−0.222	0.718
WM1	0.235	0.520	0.157
WM2	0.444	0.526	0.229
WM3	0.315	0.701	0.130
WM4	0.245	0.729	0.173
WM5	0.134	0.713	0.317
LS1	0.723	−0.321	−0.052
LS2	0.716	−0.200	−0.073
LS3	0.670	−0.228	−0.133
LS4	0.784	−0.099	−0.006
LS5	0.667	−0.408	−0.018
Extraction Method: Principal Component Analysis.			

4.4. Statistical Assumption Testing

The purpose of a histogram is to visually represent the distribution of data. This visualisation is important because it provides insight into how the data are spread out and whether it follows a normal distribution [46]. For normality, the data should follow a bell-shaped curve. By using a histogram, the shape of the data distribution can be assessed

and determine whether it meets the assumptions required for specific statistical analyses. The histogram of the regression standardised residuals, as depicted in Figure 6 below, provides a visual representation of the data distribution.

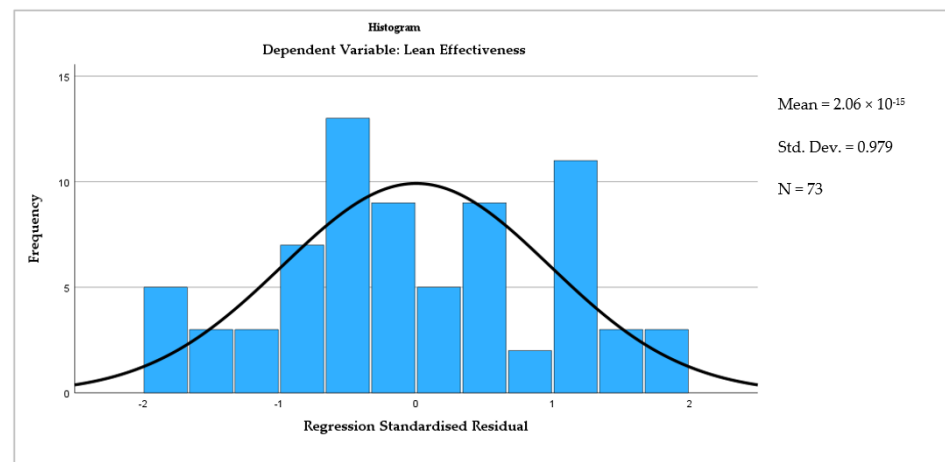


Figure 6. Histogram showing the distribution relative to Lean effectiveness.

The histogram visually represents a symmetrical distribution, with data points evenly distributed around the mean. This symmetrical pattern suggests that the data follows a normal distribution [46], which is characterised by a bell-shaped curve. This means that the majority of data are clustered around the mean, with relatively fewer data points lying farther away from the mean in either direction.

The P-P plot, also known as the probability-probability plot, compares the observed cumulative probability of the residuals to the expected cumulative probability of the residuals [49]. This plot is often used in statistics to assess how well a dataset fits a particular distribution. Figure 7 below is the P-P plot of the data.

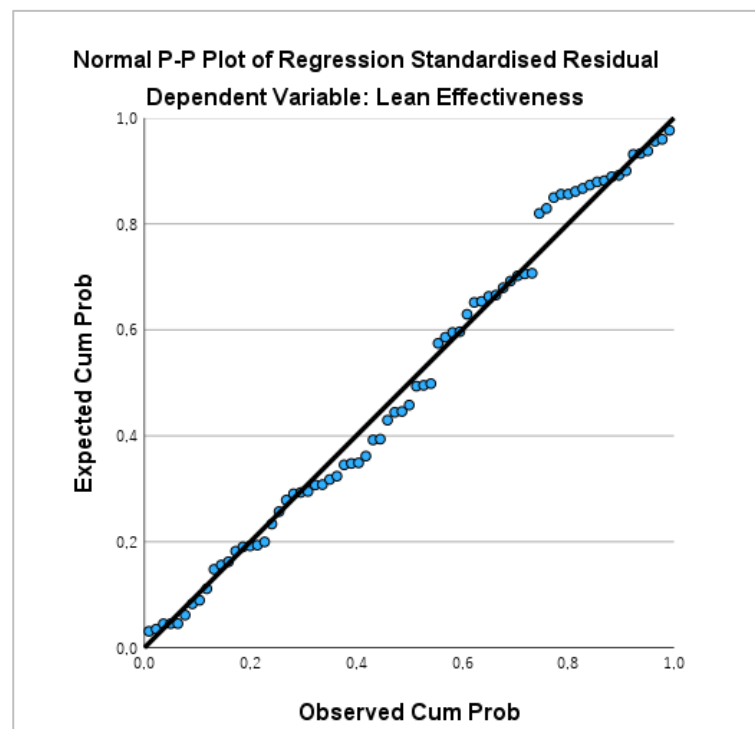


Figure 7. P-P plot assessing distribution.

The P-P plot of the data demonstrates that the points closely align with the graph line, indicating that the residuals are normally distributed [49]. This supports the histogram that suggests that the differences between the observed and expected values are symmetric and bell-shaped, in line with the characteristics of a normal distribution [46].

A scatter plot illustrates the data's normality, linearity, and homoscedasticity [50]. Figure 8 displays a scatterplot depicting the standardised predicted value against the standardised residuals.

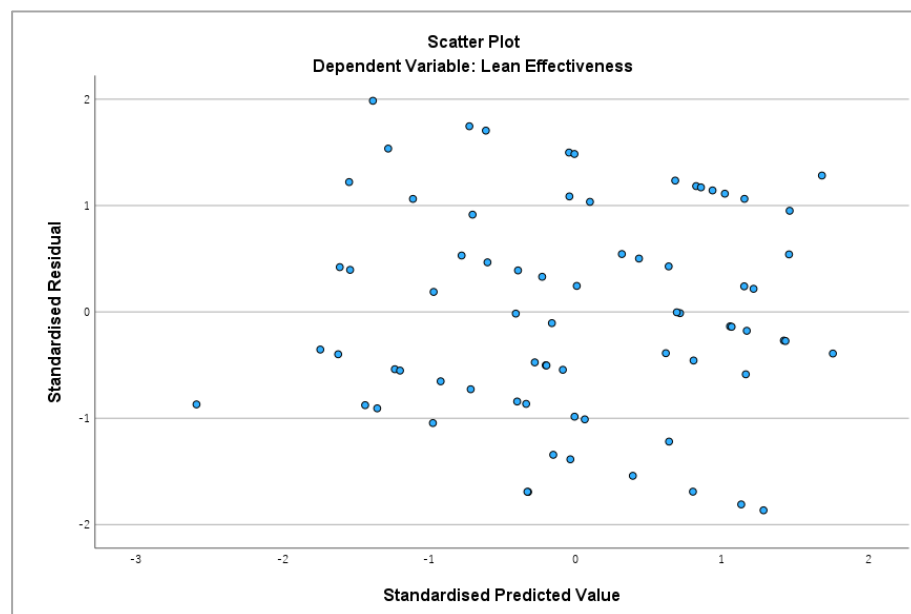


Figure 8. Scatter plot of standardised predicted value vs. standardised residual.

The scatterplot of the data shows a relatively random pattern of the scatter. This pattern suggests that the data do not appear to violate the assumptions of normality, linearity, and homoscedasticity [50]. If there were multiple outliers or signs of skewness in the data, it would be worth checking which score is involved and possibly removing it from the analysis [50].

4.5. Confirmatory Factor Analysis

The data were analysed using JASP to conduct confirmatory factor analysis (CFA), replicating the EQS package. The p -value of the chi-square test is 0.974, which is greater than the significance level of 0.05 [42]. It is preferable to have a non-significant p -value, and a non-significant χ^2 indicates that the data fits the model [50]. The p -value 0.974 indicates that there is no significant difference, making the model a good fit. The comparative fit index (CFI) value is 1.000, which exceeds the preferred value of 0.95 [50], indicating a strong fit. Additionally, according to Harlow (2014), the normed fit index (NNFI) and incremental fit index (IFI) should have values close to 1.0 for a good fit. In this case, the NNFI and IFI values for the data are 1.041 and 1.033, respectively, which exceed the ideal threshold and signify an excellent fit. The root mean square error of approximation (RMSEA) for the data is calculated to be 0.000, with a lower bound of 0.000 and an upper bound of 0.000. According to Harlow (2014), RMSEA values less than 0.05 are considered preferred [50], and in this case, the RMSEA values of the dataset indicate a good fit, suggesting that the model's fit to the data is appropriate. In addition, Harlow (2014) suggests that the goodness-of-fit index (GFI) and the comparative fit index (MFI) values should ideally be close to 1.0 [50]. Based on this, the GFI is calculated to be 0.963, and the MFI is 1.207, which supports the conclusion that the model fits the data well. The factor loadings of the data are shown in Table 7 below.

Table 7. Factor loadings.

Factor	Indicator	Estimate	Std. Error	z-Value	<i>p</i>
SE	SE1	0.673	0.078	8.651	<0.001
	SE2	0.645	0.100	6.458	<0.001
	SE3	0.838	0.085	9.861	<0.001
	SE4	0.664	0.073	9.137	<0.001
WM	WM1	0.447	0.103	4.341	<0.001
	WM2	0.614	0.096	6.424	<0.001
	WM3	0.771	0.091	8.435	<0.001
	WM4	0.763	0.089	8.607	<0.001
	WM5	0.604	0.097	6.199	<0.001
LS	LS1	0.743	0.066	11.243	<0.001
	LS2	0.677	0.085	7.978	<0.001
	LS3	0.619	0.074	8.338	<0.001
	LS4	0.727	0.083	8.809	<0.001
	LS5	0.677	0.077	8.805	<0.001
LE	LE1	0.613	0.081	7.548	<0.001
	LE2	0.914	0.082	11.164	<0.001
	LE3	0.722	0.094	7.710	<0.001

The factor loadings from the analysis reveal that all indicators have *p* values lower than 0.05, indicating that they are statistically significant. This suggests that these indicators are meaningfully associated with the underlying construct. The low *p* values confirm that each indicator is a reliable measure of the construct it is intended to represent, reinforcing the validity of the factor structure identified in the analysis. The significance of these factor loadings underscores the effectiveness of the measurement approach and strengthens the overall interpretation of the data, affirming the robustness of the identified constructs and their relevance to the study's objectives. The factor co-variances are shown in Table 8 below.

Table 8. Factor covariances.

	Estimate	Std. Error	z-Value	<i>p</i>
SE ↔ WM	−0.044	0.148	−0.300	0.764
SE ↔ LS	−0.003	0.128	−0.024	0.981
SE ↔ LE	0.074	0.120	0.615	0.538
WM ↔ LS	0.056	0.119	0.470	0.638
WM ↔ LE	0.438	0.120	3.639	<0.001
LS ↔ LE	0.144	0.121	1.191	0.234

The factor covariances suggest a statistically significant relationship between individual factors and the dependent variable, Lean effectiveness. This indicates that certain factors are more likely to have an impact on the effectiveness of Lean techniques than others. The covariance between skills and expertise and Lean effectiveness has a *p*-value of 0.538, which suggests an insignificant relationship. This high *p*-value indicates that skills and expertise may not significantly influence Lean effectiveness in the context of the study. The covariance between active work methods and Lean effectiveness has been found to have a *p*-value of <0.001. This indicates a strong relationship between the two factors, suggesting that active work methods play a significant role in determining Lean effectiveness. This

significant relationship highlights the importance of implementing effective work methods to enhance Lean outcomes. The covariance between leadership style and lean effectiveness has been found to have a p -value of 0.234. This p -value supports the finding that leadership style does not significantly impact Lean effectiveness in this context. By interpreting these p -values, insight is gained into how each factor contributes to Lean effectiveness, helping to refine and focus future research and practical applications.

5. Discussion

This research is limited to South Africa, with data collected from various companies across different provinces. This geographical focus constrains the generalisability of the findings, making them specific to the South African context. When applying these results to other regions or countries, careful consideration is required to account for different environmental and contextual factors influencing outcomes. Additionally, the high non-response rate presents a potential source of bias. The individuals who did not respond might have provided different perspectives, which could impact the overall findings. This non-response introduces a risk of incomplete data, potentially skewing the results. Furthermore, some participants might not have fully understood the survey questions, leading to inaccurate responses. One must take into account these limitations when interpreting the results, as they have the potential to impact the validity and generalisability of the findings beyond the specific South African context.

The data analysis indicates a high level of consistency, with each item linked to a specific factor, as revealed by the exploratory factor analysis. The factor loadings demonstrate that all indicators are statistically significant. However, the factor covariance analysis shows that only one of the three independent variables has a significant relationship with Lean effectiveness. This relationship is discussed further in this section.

Although the data analysis reveals that skills and expertise are statistically insignificant, suggesting no direct relationship with Lean effectiveness, the factor loadings are significant, and the EFA indicates that it is linked to a specific factor. The literature strongly supports that skills and expertise are crucial for effective Lean implementation. For instance, Bhika (2017) emphasises that competent team members are essential for project success [51]. Similarly, Mohale (2018) highlights that team capabilities are vital elements for achieving success [5]. Skills, credentials, and technical proficiency are key characteristics of successful projects [52]. Additionally, Nell and Badenhorst-Weiss (2012) argue that failing to maximise employee skills is wasteful and counterproductive in a Lean environment [3]. Digital technologies play a significant role in enhancing skills and expertise. As noted earlier, digital tools improve the planning, scheduling, and execution of tasks with minimal disruptions [26,30], supporting Lean principles. Although skills and expertise appear crucial, their impact on Lean effectiveness may require continuous adaptation and improvement, especially with evolving digital technologies in the project engineering sector.

The variable active work methods are significant, with factor loadings demonstrating their strong association with a specific factor, as indicated by the exploratory factor analysis (EFA). This aligns with the literature supporting the impact of active work methods on Lean effectiveness. Effective work methods are crucial for operational efficiency, as they ensure tasks are not handled temporarily but through consistent and structured processes [1]. Implementing Lean methods, supported by innovative digital technologies, optimises processes and enhances overall productivity and profitability [8,26]. Digital technologies, in particular, simplify and streamline company processes, leading to more efficient task completion [26]. The analysis of active work methods reflects a generally positive outlook, with participants recognising the value of effective processes, precise documentation, proactive error management, and systematic equipment maintenance. However, the variations in perceptions underscore the necessity for continuous improvement efforts to enhance organisational processes and ensure a unified understanding among employees.

The variable leadership style shows statistical insignificance in relation to Lean effectiveness, meaning there is no direct relationship. However, the factor loadings are

significant, and the exploratory factor analysis (EFA) confirms its linkage to a specific factor. The literature supports the influence of leadership style on Lean effectiveness, though the statistical analysis does not directly affect Lean effectiveness. Effective leadership is critical in the project engineering sector, with styles such as vertical, shared, and horizontal leadership impacting project outcomes [52]. The role of senior managers is crucial for success, including their ability to inspire and delegate responsibilities [5]. Integrating digital technologies into leadership practices will enhance leadership effectiveness by improving coordination and decision-making. As noted earlier, new technologies complement and enhance Lean techniques, offering substantial benefits when integrated with appropriate processes [11,26]. Although there is some variability in participant opinions, the overall positive perceptions indicate a commendable level of leadership in the industry.

6. Conclusions

This study has analysed various elements that impact the effectiveness of implementing Lean techniques in the engineering projects sector. This analysis has shown how each variable contributes to effective Lean implementation in the sector. The detailed study of each variable, which includes skills and expertise, active work methods, and leadership style, has given a comprehensive insight into the aspects within the engineering projects sector. A histogram of the data has demonstrated the normal distribution of the data. Furthermore, a P-P plot and scatterplot confirm that the data are normal and linear. The exploratory factor analysis indicates that all the variables have a strong association between factors. The confirmatory factor analysis showed that the variable active work methods is strongly associated with Lean effectiveness, while skills expertise and leadership style have an insignificant relationship with Lean effectiveness. However, the literature strongly supports the relationship between the variables.

The study findings are expected to add value to the academic and professional spaces. The findings will have several benefits for scholars and professionals. The study guides industry professionals in the engineering projects sector by identifying the key elements impacting the effectiveness of implementing Lean techniques. The insights from this research on Lean effectiveness offer significant practical applications that can enhance operations across various sectors. The findings underscore the critical role of specific factors, such as skills and expertise, active work methods, and leadership style, in optimising Lean effectiveness. Integrating these factors in the engineering sector can lead to more efficient project completion and improved overall performance. By focussing on skills and expertise, organisations can ensure their teams are well-equipped to implement Lean techniques effectively, leading to reduced waste and increased productivity. Active work methods serve to optimise processes and enhance task efficiency, while a supportive leadership style cultivates continuous improvement and fosters a culture of excellence.

It must also be understood that there is room to further investigate the subject matter of the effectiveness of Lean implementation. Future research can explore how digital technology adoption impacts project teams' collaboration, communication, and decision-making dynamics. For instance, examining how tools like collaborative software, real-time data analytics, and project management platforms influence Lean practices could yield insights into optimising Lean project delivery. Integrating advanced technologies such as AI-driven analytics or IoT-based monitoring systems might enhance real-time problem-solving and process efficiency, offering the potential for more refined Lean strategies. To strengthen these insights, empirical case analyses could examine how these technologies are practically applied within different organisational contexts. Understanding these dynamics can help develop more effective strategies for leveraging digital technology to improve Lean project outcomes. By investigating these aspects, researchers can contribute to a more comprehensive understanding of how modern digital tools can complement Lean methodologies and drive project success.

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