The impact of the Lean-Green philosophy on Zimbabwean manufacturing industry

By

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Abstract

Due to the pressure of global competitiveness and its local ramifications on manufacturing businesses in the global south, many organisations are struggling to be both profitable and environmentally compliant as local regulatory institutions begin to demand environmental friendliness from the manufacturers. Over the past few years, organisations have adopted different methodologies to improve their performance. These methodologies include Lean Manufacturing (LM) and Green Manufacturing (GM).

This research was carried out in four parts, using two methods, one qualitative and the other quantitative. The first part was based on a qualitative method where a Systematic Literature Review (SLR) was conducted using the Population, Intervention, Comparison, Outcome (PICO) format, and ATLAS.ti. This part seeks to understand the impact of the joint implementation of Lean and Green techniques on the performance of organisations from a literature perspective and propose ways to improve the synergies while limiting the mutually detrimental effects. It is apparent from the literature that implementing Green methodologies is not always complementary to Lean, but the nature of this relationship and the extent of their interaction have not been fully studied. Buoyed by the increasing demand for improved productivity and environmentally conscious manufacturing, research in the area of Lean-Green Manufacturing has experienced significant growth over the last decade, while there has not been a review of the work done since then. This first section, therefore, seeks to review Lean-Green articles published post-2013 and compare the findings to that of Dües *et al*. (2013) to understand the current state of the research. **A** systematic literature search was done to identify the Lean-Green articles from Scopus, Web of Science, and Google Scholar databases that were published post-2013. The PICO strategy was used to develop and answer research questions. ATLAS.ti version 22 was used to analyse the 141 papers and develop research themes. The results indicated that LM and GM have strong synergies, and when integrated, they tend to deliver superior organisational performance than individually. These findings agree with the pre-2013 results but with some additions, such as synergies in sustainable performance and value addition. Therefore, it helps to align LM and GM so that the full benefits of the complementary relationship are realised, and where dichotomy exists, it guides its amelioration.

The other parts were carried out using the quantitative method by collecting data through a survey and analysing the data using Structural Equation Modelling (SEM). The second part investigates the complementary nature of LM and GM on how they impact operational and environmental performance. It examines whether a combined Lean-Green implementation leads to better organisational performance than when LM and GM are implemented individually. It also explores whether being environmentally compliant leads to improved organisational performance. A survey was conducted on the Zimbabwean manufacturing industry. Out of the 782 questionnaires distributed, 302 valid responses were obtained and analysed using SEM in SMART-PLS. The results indicated that both LM and GM impact environmental and operational performance. However, GM indirectly affects operational performance through environmental performance. In addition, when LM and GM were combined, the impact was greater than when they were used separately. Therefore, the

companies that have successfully implemented LM can implement GM more easily because of their complementary nature. Integrating LM and GM reduces most forms of waste, causing improved environmental performance, community relations and customer satisfaction.

The third part evaluates whether the integration of LM and GM impacts sustainable performance more than when they are implemented separately. Also, it investigates whether being environmentally compliant has an impact on social and economic performances of organisations. It investigated whether an improvement in environmental performance can make organisations improve their economic and social performance. Thus, demonstrating that environmental compliance should not only be viewed as a requirement for compliance but as a way of improving social and economic performances. The results of the SEM showed that integrating GM and LM has a greater impact on economic, social, and environmental performance than when implemented separately. Moreover, an improvement in environmental performance led to improvement in both social and economic performances. Thus, Lean-Green positively impacts social performance by improving workers' health and safety, labour and community relations.

The last part assessed the impact of internal and external Lean-Green barriers on sustainable performance. More recently, organisations have been integrating LM and GM to harness their combined benefits, and some have successfully integrated the two methods. However, even after successful implementation, other organisations fail to achieve their goal of improving their sustainable performance due to extant Lean-Green barriers. Thus, organisations need to know and understand these barriers, because without such understanding, performance improvements may be jeopardised. Thus, this research aims to investigate the impact of internal and external barriers faced by organisations post implementation and how they affect their intended goal of improving sustainable performance. The results showed that internal and external barriers impede organisations from achieving their goals, and hence, they deserve attention.

Publications

1. A comparative review of the complementary and conflicting nature of Lean-Green implementation, Journal of Manufacturing Technology Management, Revised version under revision.

2. A hierarchical complementary Lean-Green model and its impact on operational performance of manufacturing organisations, International Journal of Quality and Reliability Management, under revision.

3. The mediatory role of the environmental performance function within the Lean-Green manufacturing sustainability complex, International Journal of Lean Six Sigma, under review.

4. A structural model for assessing the impact of Lean-Green barriers on sustainable performance, The International Journal of Advanced Manufacturing Technology, under review.

Dedication

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Because flesh and blood did not reveal this to you, but My Father who is in heaven (Matthew 16:16-17).

"He said to Paul your great learning is turning you mad" (Acts 26 vs 24).

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Abbreviations

3BL: Triple Bottom Line

3R: Reduce, Recycle and Reuse

AVE: Average Variance Extracted

CEO: Chief Executive Officer

CB-SEM: Covariance-Based Structural Equation Modelling

CSFs: Critical Success Factors

EP: Economic Performance

EVP: Environmental Performance

GDP: Gross Domestic Product

GM: Green Manufacturing

GP: Green Purchasing

GSCM: Green Supply Chain Management

HRM: Human Resource Management

HTMT: Heterotrait Monotrait ratio

IPMA: Importance-Performance Map Analysis

IoT: Internet of Things

JIT: Just in Time

KMO: Kaiser–Meyer–Olkin

LCA: Life Cycle Assessment

LM: Lean Manufacturing

OEE: Overall Equipment Effectiveness

PICO: Population Intervention Comparison Outcome

PLS: Partial Least Squares

PLS-SEM: Partial Least Squares-Structural Equation Modelling

RFID: Radio Frequency Identification

SEM: Structural Equation Modelling

SHE: Safety, Health, and Environment

SLR: Systematic Literature Review

SMEs: Small and Medium Enterprises

SP: Social Performance

SPC: Statistical Process Control

SPSS: Statistical Package for Social Sciences

TPM: Total Productive Maintenance

TQM: Total Quality Management

UAE: United Arab Emirates

VSM: Value Stream Mapping

VIF: Variance Inflation Factor

Chapter 1: Introduction

1.1 Introduction

The current business environment reflects a notable increase in competition (Abualfaraa *et al.*, 2020; Aisyah *et al.*, 2021). The higher level of competition pushes inefficient organisations out of the market and promotes the growth of efficient ones (Lartey *et al.*, 2020). This forces organisations to improve the value they create and become more customer-focused through high-quality products, short response lead times, and low product costs (Fercoq *et al*., 2016). Industries are experiencing technological advancements, and many organisations are incorporating technologies to improve their processes to remain competitive (Leong *et al.*, 2019). Different methodologies such as Lean Manufacturing (LM) (Garza-Reyes, 2015; Buer *et al.*, 2021; Saini and Singh, 2022) and Green Manufacturing (GM) (Ramos *et al.*, 2018; Machingura and Zimwara, 2020; Singh, 2021, Al-Hakimi *et al*., 2022) are now being adopted to improve customer satisfaction and increase competitive advantage (Fercoq *et al*., 2016).

GM is a manufacturing method that does not harm the environment by minimising environmental waste and different types of pollution. It aims to maximise the use of resources during the manufacturing process (Mudgal *et al.*, 2009). GM involves the use of environmentally friendly raw materials, environmental design of products, eco-friendly distribution, packing, and disposal or reuse of products (Rehman and Shrivastava, 2013). LM aims to eliminate any non-value-adding activities (Möldner *et al.*, 2020). Lean enables organisations to add value to their processes and products while removing different types of waste (Abualfaraa *et al.*, 2020). Thus, the Lean philosophy eliminates non-value-added activities in operations (Fercoq *et al.*, 2016), while the Green philosophy eliminates environmental waste (Dong *et al.*, 2020).

LM and GM have been integrated to reduce waste. Lean-Green Manufacturing allows companies to increase efficiency while lowering costs (Lartey *et al.*, 2020). Traditionally, companies were only concerned about their responsiveness, efficiency, and profitability (Cherrafi *et al.*, 2017c); however, concerns for social and environmental issues are increasing within economies (Fercoq *et al*., 2016). With continual growth in environmental awareness and increased requirements by regulators, shareholders, customers, and governments, organisations are forced to change their ways of operation (Queiroz *et al.*, 2015). The stakeholders are pushing the suppliers to be friendlier to the environment with respect to their processes and products (Acqah *et al.*, 2021). Hence, organizations implementing Lean-Green Manufacturing create a good image before their customers, stakeholders, and pressure groups, thereby creating opportunities for improved acceptance and, hence, firm growth (Lartey *et al.*, 2020).

Lean and Green Manufacturing have been separately implemented by organisations to increase competitiveness and organisational performance. Companies are already gaining competitive benefits by implementing LM practices (Núñez-merino *et al.*, 2020; Antony *et al*., 2022).). As a result, product quality, production, employee health and safety, and customer satisfaction have all improved. The adoption of Lean-Green can make organisations enhance their sustainability. The sustainability concept has been acknowledged as a way to increase competitive advantage (Kumar *et al.*, 2016). Sustainability covers the role that organisations have in satisfying humans' needs while preserving nature (Hasan and Ali, 2015). LM and GM have been implemented separately to improve organisational performance. Thus, the integration of these two methodologies can address issues around social, economic, and environmental sustainability (Bhattacharya *et al.*, 2019).

United Nations Development Programme Zimbabwe (2012) noted that Zimbabwe is lagging on greening its economy. It was highlighted that there is a need for research on GM and sustainable issues to help the country reduce pollution, waste production, environmental damage, and optimising natural resource use. In Zimbabwe, few studies have been conducted on the adoption of GM and LM practices and their impact on organisational performance. Noted examples of the application of GM are in the foundry industry (Fore and Mbohwa, 2010), leather manufacturing (Dandira *et al*., 2012), cement manufacturing (Fore and Mbohwa, 2015), mining industry (Nyakuwanika *et al*., 2021), mining and manufacturing industry (Machingura and Zimwara, 2020) and food industries Chirinda and Mutubuki (2021). Various authors have also reported on the adoption of LM in Zimbabwe. For instance, Madanhire and Mbohwa (2016b) examined the implementation of Statistical Process Control (SPC) and concluded that its adoption is very low due to the challenges faced. On the other hand, 5S was adopted to investigate Just in Time (JIT) implementation in the aluminium foundry industry (Madanhire *et al*., 2013). Maware and Adetunji (2019a) investigated the impact of different Lean practices on operational performance and found out that LM has a positive relation with operational performance. Other researchers have integrated LM with other manufacturing techniques, such as Lean Six Sigma (LSS) (Goriwondo and Maunga, 2012; Karombo and Rutiri, 2014).

Although Lean-Green helps organisations to improve, such improvements are hindered by internal and external barriers (Yadav *et al.*, 2020). Internal barriers are hindrances that occur inside the organisation, for example, lack of top management commitment and lack of training and education (Anis *et al.*, 2019). External barriers are the hindrances that occur outside the organisation for example, uncertain future legislation (Jabbour *et al.*, 2016). Therefore, these barriers that impede organisations from attaining their goals must be addressed.

1.2 Background of the research

The economy of Zimbabwe has been unstable since the introduction of multicurrency in 2009, and the growth of the Gross Domestic Product (GDP) has not been steady because over the past years, as soon as it starts growing, it declines again (Maware and Adetunji, 2019a). The World Bank (2021) pointed out that in 2019 and 2020, the GDP of Zimbabwe decreased by 8%. While the rapid industrialisation of countries around the world has led to a significant improvement in the economies, it also negatively impacted the environment (Ramos *et al.*, 2018). Furthermore, customers have increased their demand for improved quality and lower cost of products, and more recently, reduction of the environmental effects associated with the production of goods and services (Ramos *et al.*, 2018; Garza-Reyes, 2015). Leme *et al.* (2018) acknowledged that environmental issues need to be considered as a competitive differentiation tool. In such a business environment, there is a need for manufacturing organisations to implement the methodologies that can help them to survive. As a result, manufacturing companies adopt different methodologies to address environmental issues (Ramos *et al.*, 2018), improve customer satisfaction, and gain a competitive advantage.

In addition, resources are becoming scarce, making them more expensive; thus, the minimisation of their consumption is now the aim of most organisations (Fercoq *et al*., 2016). The environmental issues faced nowadays have encouraged organisations to go green. Issues like the greenhouse effect, noise pollution, ecosystem imbalance, loss of biodiversity, air pollution, ozone layer depletion, and toxic materials have drawn concern from the stakeholders. Pollution is detrimental to the environment as it causes health hazards such as lung cancer, heart diseases, and stroke, amongst others (Kuo and Lin, 2020). Every year, pollution causes an average of nine million deaths worldwide, which is 16% of the total deaths (Kuo and Lin, 2020). Companies are adopting GM intending to contribute directly to improvements in environmental management, and to indirectly gain a competitive advantage (Bhattacharya, *et al*., 2019). GM leads to improved products and processes, the image of the company, and competitiveness (Ramos *et al.,* 2018). The adoption of GM has several advantages, including a reduction in raw material consumption, reduced effluent waste, reduced accidents, reduction in solid waste, cost reduction and compliance with environmental regulations (Ramos *et al.*, 2018). Organisations are also adopting LM to reduce Lean waste, increase value, improve product quality, reduce costs and gain competitive advantage (Núñez-merino *et al.*, 2020). Thus, organisations have been focusing on waste reduction through implementing Lean-Green (Dong *et al.*, 2020; Singh, 2021, Al-Hakimi *et al*., 2022).

The interest in integrating Lean and Green manufacturing has increased in industry and academia (Leme *et al.*, 2018). The integration of LM and GM has gained popularity due to their synergistic effect and the improvements they bring to the organisations (Ramos *et al.*, 2018; Leme *et al.*, 2018). LM and GM are complementary and are governed by three main principles: waste minimisation, process centredness, and a high degree of people involvement (Fercoq *et al*., 2016). They both seek to solve problems and search for improvements through employee involvement (Ramos *et al.*, 2018). Although LM and GM have different approaches and origins, they both aim at cost reduction through efficient resource utilisation and waste minimisation (Bhattacharya *et al*., 2019). Although LM and GM focus on different types of waste, organisations are integrating LM and GM as both approaches focus on waste reduction (Farias *et al.*, 2019; Leong *et al.*, 2020; Dües *et al.*, 2013; Leme *et al.*, 2018). Manufacturing companies can simultaneously implement Lean and Green philosophies to reduce costs, improve the company image, reduce risks, increase revenue (Fercoq *et al*., 2016), improve productivity, optimise resource usage, and improve the quality of products and services (Ramos *et al.*, 2018). Leong *et al.* (2020) supported this by acknowledging that waste minimisation and improved operational performance are achieved by implementing Lean-Green. Integration of LM and GM can make manufacturing companies competitive and increase profits, which is the goal of these organisations (Bhattacharya *et al*., 2019; Fercoq *et al*., 2016). Thus, integrated Lean and Green practices are being regarded as vital techniques that are deployed to improve financial and environmental performances (Kuo and Lin, 2020).

Green practices are realised as a big chance to increase Lean performance; therefore, those Lean companies that adopt GM attain better Lean results compared to those organisations that do not (Fercoq *et al*., 2016; Cherrafi *et al.*, 2018). Ramos *et al.* (2018) emphasised that Lean can be considered Green as it acts as a catalyst to improve GM results. Therefore, researchers are exploring the synergistic effect between the two concepts to attain common benefits (Bhattacharya *et al*., 2019).

However, Venugopal and Saleeshya (2019) stated that manufacturing organisations focus primarily on economic sustainability, followed by social sustainability and lastly environmental sustainability. The environmental bottom line has been of the least importance to many organisations because it is the one that does not seem to have the most obvious and immediate benefit to the organisation. This is because it directly affects the environment, unlike social and economic sustainability, which are more directly linked to organisational return and image. It is apparent that the economic bottom line is of interest to most organisations due to the profitability implications, while the social bottom line has a more direct impact on the image of the organisation due to the perception within the local community, which seems to buy them good social capital, and then translates to increased market share, and hence, profitability in the future. According to Michlak and Schucht (2004), organisations will comply with environmental regulations only if the penalty for environmental violation is greater than the cost of being compliant. Thus, it seems some organisations weigh their options: either polluting the environment and paying a small fine or implementing environmental management techniques at a cost (Walton *et al*., 1998). As a result, some prefer paying fines, as they do not realise how environmental performance can help them improve their economic performance, which is of main interest to them. Therefore, most companies view environmental management issues as an issue of compliance with the regulations only. However, in this study, the researcher wants to investigate if environmental management is more than a compliance issue, being a means of improving social and economic performances. That means in order for organisations to maximise their economic performance, they should be concerned, not only about improving their financial growth, but should also focus on non-financial performances such as the environment (Achim and Borlea, 2014). Once organisations realise the impact of their environmental performance on the economic performance, most of them will opt to implement environmental management techniques, not for the sake of compliance only, but for the economic gains as well.

There is a realisation today of the need for organisations to measure their performance not only on the economic indices of profitability as has traditionally been done, and hence the progressive move towards the Triple Bottom Line (3BL) measures. This is because, the demands from the customers are no longer limited to the traditional competitive factors like fast delivery and high quality products, as the customers are now also interested in sustainability issues (Leme *et al*., 2018). Also, stakeholders like the government and communities are asking manufacturers to be environmentally conscious and opt for greener services and products (Leme *et al*., 2018; Baumer-Cardoso *et al*., 2020; Acqah *et al*., 2021). These changes in ecological requirements and customer demand have encouraged organisations to pursue environmental efficiency (Farias *et al*., 2019), and those companies that are not environmentally compliant may lose some of their customers. Different environmental aspects are now being considered before doing business; for example, the companies' energy consumption, green design, solid waste management, and green materials philosophy (Fercoq *et al*., 2016). Thus, the environmental aspect needs to be regarded as a competitive tool by organisations desiring to improve customer satisfaction (Leme *et al*., 2018), and as a result, organisations are considering adopting strategies to improve environmental performance.

1.3 Problem statement

The increase in environmental awareness can significantly affect companies in terms of customer satisfaction. Nowadays, many customers require companies to be friendlier to the environment (Lartey *et al.*, 2020) or risk losing business. GM and LM have proved to help improve the company's environmental and operational performance, thus meeting customer needs (Hassan and Jaaron; 2021; Buer *et al.*, 2021; Saini and Singh, 2022) This can, therefore, hugely impact market share and competitive advantage.

Integration of LM and GM could answer many questions of organisations, including the need for improvement in their operational and environmental performances (Fercoq *et al*.,2016). Recent work highlighted some gaps and areas of concern regarding the adoption of LM and GM. Although GM is complementary to LM in environmental efficiency improvement, Farias *et al*. (2019), acknowledged that there isn't much proof on the successful integration of LM and GM. Garza-Reyes (2015) added that there is minimal and inconclusive research on the impact of Lean-Green techniques on organisational performance. The elements that enable the assessment of Lean-Green on performance are still unknown (Farias *et al.*, 2019). Many organisations have not benefited from Lean-Green owing to a lack of a well-organised implementation system (Leong *et al.*, 2019; Leong *et al.*, 2020). Hence, its adoption has not received enough attention (Leong *et al.*, 2020). Siegel *et al*. (2019) noted that a comprehensive conceptual framework for integrating LM and GM is lacking. Therefore, it is still unclear how to put it into practice to transform organisations to be more sustainable (Leme *et al.*, 2018). Sumant and Negi (2018) highlighted that Indian Small and Medium Enterprises (SMEs) experience difficulties implementing the LM and GM practices, and little work has been published on such implementations. Bhattacharya *et al*. (2019) indicated that most academic research examined LM and GM implementation separately and not simultaneously.

Furthermore, it seems like developing countries lag in integrating LM and GM compared to developed countries. Hence, there is a lack of a standard measurement model and a commonly accepted model of performance measurement to assess the impact of implementing such methodologies (Maware and Adetunji, 2019a). As a result, companies are not sure which LM and GM practices to adopt and the likely effect of such adoption on their performance. There is much confusion when new adopters want to implement such techniques because companies may not know what to do or expect, leading to haphazard implementations (Maware and Adetunji, 2019a). This makes management hesitant and skeptical about implementing these improvement methods (Maware and Adetunji, 2019b). As a result, it looks as if companies are wary of implementing GM and LM as they believe the implementation is probably just a resource consumption process with little or no tangible benefits to the organisations.

Since both LM and GM are based on continuous improvement and waste reduction, it is essential to explore the effect of their joint implementation on organisational performance (Farias *et al.*, 2019). Further research is therefore needed to address the gaps in Lean-Green implementation. To the best knowledge of the student, no study has been conducted to examine the complementary effect of Lean-Green adoption on organisational performance. Most of the studies that have been conducted have focused on the impact of implementing LM and GM separately. Thus, this research investigates whether integrating LM and GM yields better results than implementing one of these philosophies alone. By considering this, the research aims to develop standard Lean-Green assessment models that can be adopted by manufacturing companies using data from Zimbabwe's manufacturing industry.

The simultaneous implementation of LM and GM has recently piqued the interest of researchers, and many benefits have been reported, including improvement in economic, social, and environmental performances. Although several studies have reported on the benefits of simultaneously implementing LM and GM (Dues *et al*., 2013; Fercoq *et al*., 2016), attaining such benefits is impeded by many barriers. Thus, Lean-Green barriers make it difficult for organisations to achieve the intended results. Various researchers have highlighted the barriers faced when implementing LM and GM, which are generally the same, and should reasonably be the same for Lean-Green implementation. However, organisations still face several challenges during the post implementation phase in trying to make Lean-Green attain its intended goal. Thus, it may not be sufficient to only examine the barriers faced during the implementation process, but also those faced post-implementation, as these can hinder the achievement of sustainable performance. Thus, in this research, the student considers the Lean-Green barriers faced post implementation that impede organisations from attaining the improvement goals of sustainable development. This enables organisations to understand that Lean-Green barriers do not end at the implementation stage, but are also encountered afterward; hence, they should aim towards effective change management. Also, if such barriers are not identified and mitigated, the failure of firms to realise improvements in sustainable performance might lead to the perception that Lean-Green has no tangible benefits. Since organisations aim to improve their sustainable performance, it is essential to demonstrate how such barriers impede the improvement process.

Hence, organisations should familiarise themselves with these barriers, especially in the developing world, where such research seems to be lagging (Singh *et al*., 2020). Even though the issues on the barriers have been discussed before, most researchers focused on the barriers faced in implementing either LM or GM; hence, there is a need to examine the post implementation phase barriers. For example, Sarhan and Fox (2013), Shang and Pheng (2014), Kanafani (2015), Abu *et al.* (2019) identified the barriers faced in implementing Lean practices. On the contrary, Luthra *et al.* (2011), Khiewnavawongsa and Schmidt (2013), Mathiyazhagan *et al.* (2013), Mittal *et al.* (2013), Mittal and Sangwan (2014), Ghazilla *et al.* (2015), Jabbour *et al.* 2016, Mathiyazhagan *et al.* (2017), Kaur *et al.* (2017), Singh (2020) highlighted the barriers to GM implementation.

In addition, few studies have been done to test the relationship between the Lean-Green barriers and organisational performance. Most researchers identified the barriers encountered during the implementation stage and not after implementation; also, these studies did not examine the relationships between these barriers and organisational performance. Few studies have been done focusing on the relationship between LM or GM barriers and organisational performance. For instance, Mathiyazhagan *et al.* (2017) applied SEM to examine the barriers to Green

Supply Chain Management (GSCM) adoption and their impact on economic benefits and market image. In addition, Jabbour *et al*. (2016) also applied SEM and developed a model that shows the relationship between the barriers and operational and green performance. Mittal and Sangwan (2014) focused on testing the relationship between internal, economic, and policy barriers that affect the performance of organisations. This research extends this knowledge by examining the relationship between Lean-Green barriers and their effects on the 3BL. To fully explore the relationships, the barriers were classified into external and internal barriers, as done by Jabbour *et al*. (2016).

To help companies survive the existing economic hardships, research should be conducted, focusing on the impact of Lean-Green on the organisation's performance. There is a great need to research these issues so that companies can understand the importance and benefits associated with their implementation. This research will help companies realise the benefits of GM and LM’s simultaneous implementation. It is believed that through such implementation, companies will significantly benefit at the same time protecting the environment.

1.4 Research questions

In this section, the research questions are presented, and the methodology adopted to answer each of the questions. The first research question was answered through the SLR approach, a qualitative method, and all the subsequent questions were addressed using SEM, a quantitative method.

The study's goal is to find answers to the following research questions:

RQ1. How complementary or contradictory are the impacts of implementing Lean and Green techniques in manufacturing organisations?

This question was addressed by reviewing the published literature post the last major review by Dues *et al*. (2013). Various studies that have been done have focused on the implementation of LM and GM separately. However, over the past few years, there has been growth in research interests on Lean-Green. As a result, a lot of work has been done since Dues *et al*. (2013) to further the research on Lean-Green implementation. Considering the growth of the research on Lean-Green, it is believed that issues on Lean-Green Manufacturing are due for review. Leong *et al*. (2019) also pointed out that the need for studies on Lean-Green Manufacturing is increasing rapidly. Thus, this study is carried out to understand the mechanism for integrating LM and GM in such a manner that enhances operational performance and compliance with extant regulations.

RQ2: Does the joint implementation of LM and GM lead to better organisational and sustainable performance than when LM and GM are implemented individually?

Previous studies focused on the individual implementation of GM and LM and their effects on organisational performance. Since LM and GM have synergies which include waste reduction, continuous improvement, and people involvement (Fercoq *et al*., 2016), they can therefore be implemented simultaneously. However, more authors have focused on the individual impacts of either LM or GM without paying attention to their combined effects. Therefore, it is critical to examine the degree to which the combined Lean-Green improve the performance of organisations and clarify if it is better to integrate Lean-Green or stick to individual implementations.

RQ3: Does the improvement in environmental performance increase the economic and social performance of organisations?

Manufacturing organisations are interested in improving their economic performance as it is directly linked to profits. As a result, some are not interested in improving their environmental performance and prefer paying fines for environmental violations. On the other hand, others are implementing environmental management techniques to satisfy the requirements of regulators since they are not sure how such implementation can enhance their overall sustainable performance. Thus, it is critical to demonstrate how environmental performance can make organisations improve their economic and social performance leading to improved sustainable performance.

RQ4: To what extent do internal and external Lean-Green barriers impede organisations from attaining improved sustainable performance?

Many authors have identified the barriers encountered during the implementation of either LM or GM. However, barriers are not only faced during the implementation stage, but post implementation as well and these barriers faced after the implementation process can also hinder organisations from achieving their goals. Hence, it is crucial to also examine these Lean-Green barriers and the extent to which they impede organisations from realising improvements in sustainable performance.

1.5 Research objectives

The study's objectives are as follows:

1. To determine how complementary or contradictory the impacts of implementing Lean and Green techniques are in manufacturing organisations. This would be accomplished by:

    - Identifying the synergies and divergencies between LM and GM through a SLR of papers focusing on Lean-Green implementation in the manufacturing industry.

2. To evaluate the impact of implementing the combined Lean-Green approach on the environmental and operational performance of the manufacturing organisations in Zimbabwe. This would be accomplished by:

    - Developing a SEM model that evaluates the impact of LM and GM on environmental and operational performance of the organisations.
    - Analysing the impact of LM and GM on environmental and operational performance using SMART PLS 3.

3. To analyse the mediatory role of environmental performance function within the Lean-Green manufacturing sustainability complex. This would be accomplished by:

- Developing a model using the SEM method that evaluates the impact of LM and GM on economic and social performance through environmental performance.
- Analysing the impact of Lean-Green on socio-economic performance through environmental performance using SMART PLS 3.

4. To investigate the extent to which internal and external Lean-Green barriers impede organisations from attaining improvements in sustainable performance. This would be accomplished by:

- Developing a SEM model that evaluates the impact of Lean-Green barriers on attaining improvements in sustainable performance
- Analysing the extent to which the Lean-Green barriers hamper organisations from attaining improvements in sustainable performance using SMART PLS 3.

1.6 Contribution to knowledge

Lean-Green standard measurement models shall be developed that can be used by different industries to measure the impact of Lean-Green implementation on sustainable organisational performance. It is believed that with a standard model, Lean-Green can be easier to implement. With knowledge of LM and GM towards sustainable organisational performance, many companies may be encouraged to implement these philosophies. This can be done using standard measurement models, hence, eliminating haphazard implementations. This does not only benefit the current Lean-Green implementations, but future implementations as well. This will make companies perform better, reduce the negative environmental effects caused by their operations and also minimise the consumption of natural resources. Therefore, companies, communities, and future generations will benefit.

Additionally, a model shall be developed that assesses the extent to which internal and external Lean-Green barriers hinder organisations from attaining their intended goal. Thus, providing knowledge on what barriers are likely to be faced and the impact of such barriers on accomplishing enhanced and sustainable performance. This will help new adopters to understand that barriers are also faced post implementation and help them prepare accordingly.

1.7 Thesis framework

The thesis comprises six chapters: the introductory chapter, literature review, methodology, results, discussion, and conclusion. The thesis framework is shown in Figure 1.1

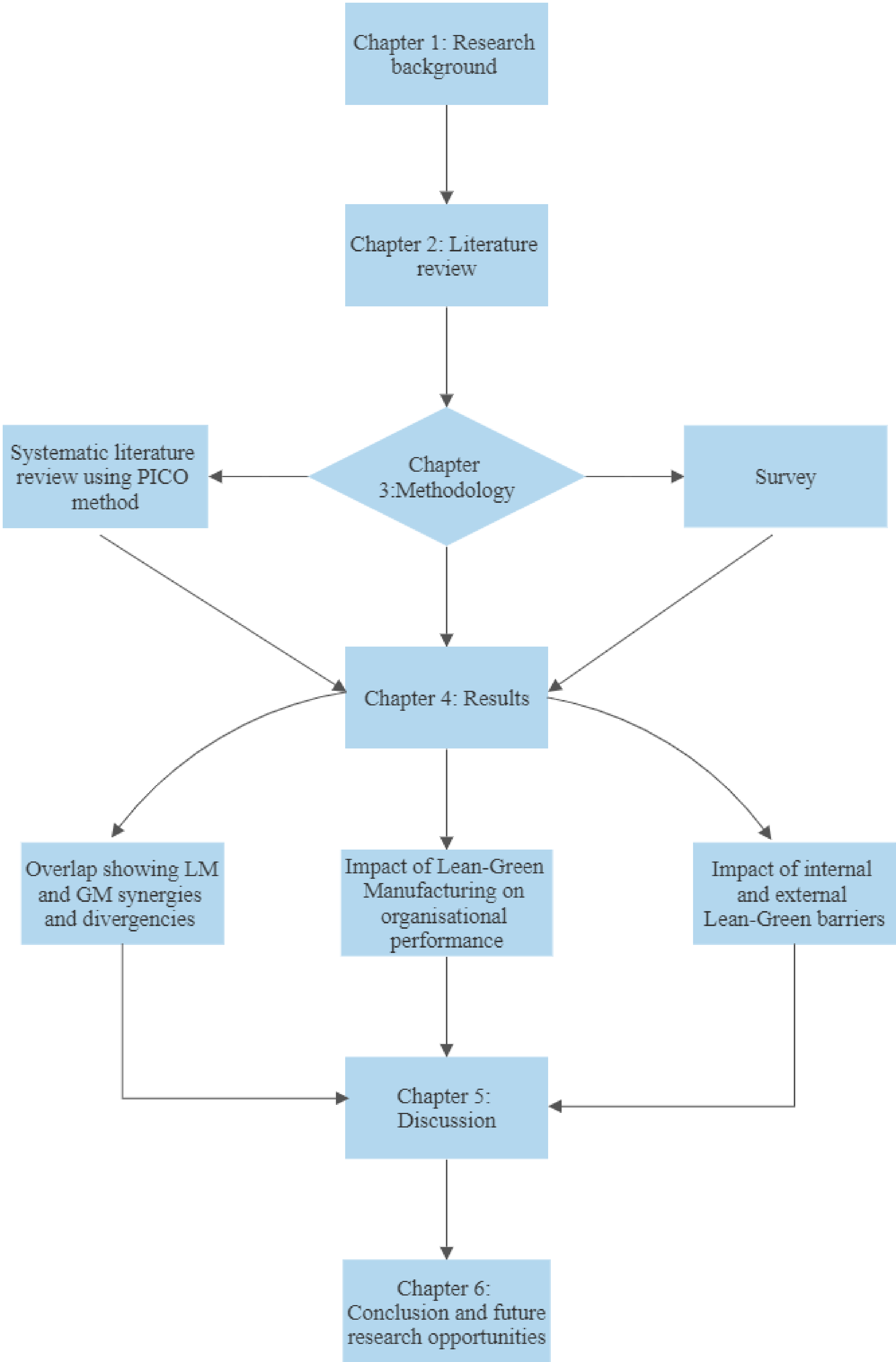

Figure 1.1: Thesis framework

1.7.1 Chapter 1: Introduction

Chapter 1 highlights the background of the research, problem statement, research question, objectives, and the contribution of the research to the current literature.

1.7.2 Chapter 2: Literature review

This chapter presents the literature on GM and LM. It highlights the adoption of LM and GM by organisations in different countries with a particular focus on the Zimbabwean manufacturing industry. In addition, it identifies the research gap.

1.7.3 Chapter 3: Methodology

The two methods used in this research are outlined in this section. The chapter outlines the use of the qualitative and quantitative methods. The qualitative method employed SLR using PICO and ATLAS.ti coding in identifying the synergies and divergencies between LM and GM. The quantitative method used SEM to develop and analyse the research models. In addition, the chapter highlights the data collection and cleaning process. The use of Statistical Package for Social Sciences (SPSS) version 26 and SMART PLS 3 in data analysis was also discussed.

1.7.4 Chapter 4: Results

Chapter 4 highlights the results of this study. It discusses the complementary and conflicting areas of LM and GM. It indicates the synergies that can be exploited through the integration of LM and GM and the trade-offs that are encountered. Furthermore, it shows the impact of LM and GM on organisational and sustainable performance of manufacturing organisations. Also, it investigates the mediatory role of environmental performance on the impact of Lean-Green Manufacturing on socio-economic performance. It also demonstrates whether the integration of LM and GM yields better results than either LM or GM. The chapter ends by indicating the impact of internal and external Lean-Green barriers on sustainable performance. It was found that when LM and GM are adopted simultaneously, the improvements are greater than individual implementation. Also, environmental performance was found to mediate the relationship between Lean-Green and socio-economic performance. Finally, both internal and external Lean-Green barriers were found to negatively impact sustainable performance improvement.

1.7.5 Chapter 5: Discussion

This chapter delves into the details of the findings obtained in this research. It compares the results to those obtained by various authors. It also gives an insight into whether implementing Lean-Green is a viable option.

1.7.6 Chapter 6: Conclusion and future research opportunities

The research is summarised in this chapter by answering the research questions. In addition, it outlines the managerial, social, and practical implications of the research. Also, the research highlights the limitations and areas for future research opportunities.

1.8 Chapter conclusion

This chapter highlighted the background of research about LM and GM and the problem statement. It also indicates the objectives and research questions. In addition, it gives a framework for the research that outlines brief information about the other chapters.

Chapter 2: Literature review

2.1 Lean Manufacturing

Lean Manufacturing (LM) is a methodology aimed at eliminating waste (Prasad *et al.*, 2016; Abu *et al.*, 2019; Lartey *et al.*, 2020; Viles *et al.*, 2021), increasing value-added by operations (Indah *et al.*, 2020) and increasing customer focus (Fercoq *et al*., 2016). LM refers to a system that uses fewer inputs to produce the same output as a traditional mass production system while offering the end customer greater variety (Kovilage, 2020). LM considers waste as using resources for any goal that does not create value for the customer (Pampanelli *et al*., 2014). It eliminates non-value-adding activities through continuous improvement (Ghobadian *et al*. 2020; Möldner *et al*., 2020). Fercoq *et al*. (2016) pointed out that traditionally, LM focused on seven types of waste: defects, over-processing, excessive transportation, over-production, unnecessary inventory, unnecessary motion, and waiting. In addition to the seven wastes, Fercoq *et al*. (2016) also noted that environmental waste could be viewed as the eighth waste. Other researchers have considered non-utilised talent as the eighth waste (Lartey *et al.*, 2020). These wastes are non-value-adding activities that clients are not keen to pay for (Cherrafi *et al.*, 2018). LM has contributed to a high level of production efficiency for decades and has been denoted as a perfect way to run manufacturing organisations (Pampanelli *et al*., 2014). It has been adopted in management practice because it provides ways to achieve performance improvement (Marodin *et al.*, 2019; Kuo and Lin, 2020). LM is related to the satisfaction of the customers and productivity improvement leading to enhancement in product quality, cost reduction and processes' speed (De *et al.*, 2020). Manufacturing organisations intend to adopt LM to reduce waste, lead time, and increase the variety of products (Narkhede *et al.*, 2020).

2.1.1 Lean Manufacturing and sustainability

LM has been adopted by manufacturing companies to improve their organisational performance. More recently, Lean practices have been implemented to enhance the sustainability of organisations. For instance, Maware and Adetunji (2019a) examined the adoption of LM practices in the Zimbabwean manufacturing industry and realised an improvement in flexibility, speed, and dependability. A case study in Indian Small and Medium Enterprises (SMEs) highlighted that adopting LM helps attain environmental, social, and economic improvements (De *et al.*, 2020). Arumugam *et al.* (2020) also applied social and technical Lean practices in India and noted an improvement in financial, employee, and operational performance. The study in various countries by Bortolotti *et al.* (2015) noted that LM improves quality, delivery, flexibility, and cost performance. Yang *et al.* (2011) conducted research in different international organisations and pointed out that market, environmental, and financial performance are all improved through LM adoption. The study in the Italian manufacturing industries showed that LM leads to the growth of organisations and improved operational performance (Bevilacqua *et al.*, 2017).

2.1.2 Lean Manufacturing and developing countries

Researchers have been conducting studies to examine LM implementation in developing countries in the past years. For instance, Santos Bento and Tontini (2018) applied LM in the Brazilian manufacturing sector and determined that LM leads to improved operational performance. In addition, research in the Brazilian automotive industry indicated that Just in

Time (JIT), and Total Productive Maintenance (TPM) cause a reduction in lead time and inventory, respectively (Marodin *et al.*, 2019). Furthermore, Kamble *et al.* (2020) integrated Industry 4.0 and LM in the Indian manufacturing sector and noted that such integrations lead to enhanced sustainable organisational performance.

2.1.2.1 Lean Manufacturing implementation in Zimbabwe

Various researches on the application of LM techniques in Zimbabwe have been published. Maware and Adetunji (2019a) reported an improvement in operational performance by applying Jidoka, stability and standardisation, JIT, and employee involvement. A study by Muchaendepi *et al.* (2019) in SMEs concluded that JIT is the most deployed strategy for inventory management and performance improvement. Madanhire and Mbohwa (2016a) applied JIT and Total Quality Management (TQM) in the aluminum foundry industry and realised an improvement in operational performance. A case study by Ngwenya *et al*. (2016) examined the challenges that are faced in implementing TQM at a beverage company. Some of the major challenges pointed out are economic challenges, resistance to change, and inadequate funding. Mushipe (2012) reported the influence of Human Resources Management (HRM) on organisational performance in the food industry. Kudoma and Madzikanda (2014) developed a TQM framework to help SMEs improve their quality. Goriwondo *et al*. (2011a) reported improved machine utilisation and Overall Equipment Effectiveness (OEE) through TPM adoption in the pharmaceutical industry. In the bread manufacturing industry, Goriwondo *et al*. (2011b) applied Value Stream Mapping (VSM) and achieved a reduction in defects, inventory and motion.

2.2 Green Manufacturing

Green Manufacturing (GM) is the application of environmental, economic, and technological strategies to processes and products to improve the utilisation of raw materials, energy (Dong *et al.*, 2020), and water through the reduction, recycling, and non-generation of waste (Ramos *et al.*, 2018). According to Abualfaraa *et al.* (2020), GM is an approach that focuses on removing environmental waste such as solid waste, waste water, and gas emissions. GM's goal is to manufacture products that do not harm the environment (Hasan *et al.*, 2021). Thus, it minimises the environmental damage by manufacturing processes, products and services (Fercoq *et al.*, 2016). GM minimises the negative environmental effects of the production processes and consumption of goods and services, while improving the company's environmental footprint. It protects the environment by reducing toxic materials, using environmentally friendly processes and raw materials, designing for the environment, recycling and remanufacturing (Leme *et al.*, 2018). Inspired by LM, Hines (2009) proposed the eight GM wastes, and these are greenhouse gases, excessive power usage, pollution, eutrophication, poor health and safety, excessive water usage, excessive resource usage, and rubbish. Hence, its adoption is anticipated to improve environmental sustainability by reducing solid waste, air pollution, waste water, and consumption of hazardous materials (Green *et al.*, 2012).

Furthermore, GM aims to reduce the consumption of raw materials, thus saving costs and conserving them for future generations (Viles *et al.*, 2021). Furthermore, it minimises energy consumption and waste generation by considering the entire life cycle of the products (Ramos *et al.*, 2018). Reduction in the consumption of raw materials is vital as the overuse of these resources leads to massive environmental damage (Fercoq *et al*., 2016). Moreso, the fast depletion rate of natural resources makes them scarce and expensive, making GM implementation a viable option.

2.2.1 Green Manufacturing and sustainability

Recently, manufacturing organisations have become conscious of the role that environmental performance plays in such a competitive market (Mafini and Loury-Okoumba, 2018). GM has emerged as a new manufacturing methodology that has gained popularity due to its role in attaining environmental sustainability (Mafini and Loury-Okoumba, 2018). Therefore, manufacturing companies are beginning to adopt GM to please the customers who are demanding that manufacturers use environmentally friendly processes (Green *et al*., 2012). The application of Green Supply Chain Management (GSCM) in the United States of America by Green *et al*. (2012) led to improved economic and environmental performance, which affects social performance. A GM framework was developed and validated in the Indian steel industry, which provides ways to achieve sustainability by applying GM practices (Rehman *et al*., 2013).

2.2.2 GM and developing countries

Manufacturing organisations in developing countries have been adopting GM practices to improve their organisational performances. The adoption of Green operational practices in Brazil improved Green performance through reduced waste, emissions, and material consumption (Soubihia *et al*., 2015). Research among South Africa's manufacturing SMEs concluded that GSCM practices cause an improvement in operational performance (Mafini and Loury-Okoumba, 2018). In Malaysia, Hasan and Ali (2015) investigated the impact of implementing Green marketing and realised improvements in organisational performance.

2.2.2.1 Green Manufacturing and its implementation in Zimbabwe

Zimbabwe's manufacturing industry has shown evidence of GM deployment. Mbohwa (2002) highlighted that Zimbabwe could learn a lot from the Japanese companies in implementing GM. A noted example is the development of GM technologies such as electronic environmental management. Mutubuki and Chirinda (2021) analysed how GM can be used to reduce waste in the food industry. Some of the suggested Green practices are Reduce, Recycle and Reuse (3R) and green packaging. Masike and Chimbadzwa (2013) applied Life Cycle Assessment (LCA), environmental accounting, eco-efficiency, energy, and waste management in the foundry industry to improve material, operations, environmental, and energy efficiency. Machingura and Zimwara (2020) outlined a GM framework that can be adopted by manufacturing companies in Zimbabwe. Nyoni *et al*. (2011) conducted a case study in the tobacco processing industry to shed more light on how GM can be used as the basis for ISO 14001 implementation. The application of GM in the oil industry generated savings through pollution prevention and reduced consumption of resources (Madanhire and Mugwindiri, 2012). The case study by Mugwindiri and Mushiri (2016) in various manufacturing industries concluded that GM implementation leads to cost reduction and conservation of resources such as water.

2.3 Lean-Green Manufacturing

Lean-Green is a new concept that integrates LM and GM to reduce waste (Vinayagasundaram *et al.*, 2020; Viles *et al.*, 2021), increase value, and improve environmental sustainability (Rezende *et al.*, 2021).

2.3.1 Integration of LM and GM in developing countries

Over the past few years, LM and GM have been implemented separately by manufacturing companies seeking to improve their operations (Rodrigues *et al.*, 2020). Although improvements were achieved, Baumer-cardoso *et al.* (2020) highlighted that when combined, LM and GM yield better results than alone. Although no case of LM and GM integration has been reported in Zimbabwe, other developing countries have been researching this issue. A study by Farias *et al.* (2019) in Brazil, developed a framework to evaluate the impact of LM and GM on organisational performance. The study conducted in China by Huo *et al*. (2019) concluded that Lean-Green positively impacts sustainable development. Thanki *et al.* (2016) identified ISO 14001 and TPM as the most influential Lean-Green practices in India. Dawood and Abdullah (2018) applied VSM and 3R in Iraq's cement manufacturing company and discovered that these practices are significant in such industries.

2.3.2 Lean-Green and sustainable development

For the past years, organisations have been implementing LM and GM separately to improve organisational performance. Several researchers have reported on the individual implementation of LM and GM towards sustainability (Kovilage, 2020). Nawanir *et al.* (2020) reported that implementing LM in Malaysian SMEs leads to improvement in the Triple Bottom Line (3BL). On the other hand, the study conducted in various developed countries by Longoni and Cagliano (2015) highlighted that the involvement of employees and executive managers affects the alignment of LM practices which tend to affect the social and environmental performance. Furthermore, in the Malaysian manufacturing industry, Iranmanesh *et al.* (2019) found out that Lean practices improve sustainable performance. In addition, the study in Ghana noted that GM has a positive impact on the three dimensions of sustainability (Afum *et al*., 2020a). Another research in the Ghanaian manufacturing industry also pointed out the positive impacts of Green practices on sustainable performance (Afum *et al*., 2020b). Recently, organisations have been enthusiastic about implementing methodologies that help them become sustainable and increase competitive advantage (Kumar *et al.*, 2016), LM and GM included. The study in the United Kingdom packaging SMEs concluded that integrating LM and GM has a synergistic and positive effect on environmental and operational performance (Choudhary *et al.*, 2019). Furthermore, the study in Chinese manufacturing organisations showed that the combined LM and GM have a greater impact on the 3BL on both customers' and suppliers' sides than when implemented individually (Huo *et al*., 2019). Also, the research done by Green *et al.* (2019) in US manufacturing firms, realised greater improvements in environmental sustainability and operational performances when LM and GM were combined.

2.4 Synergies and divergencies between LM and GM

2.4.1 Summary for pre-2013 Lean-Green studies: the road to Dües *et al.* (2013)

This section highlights a summary of the findings by Dües *et al*. (2013) and the supporting references from the research done before 2013.

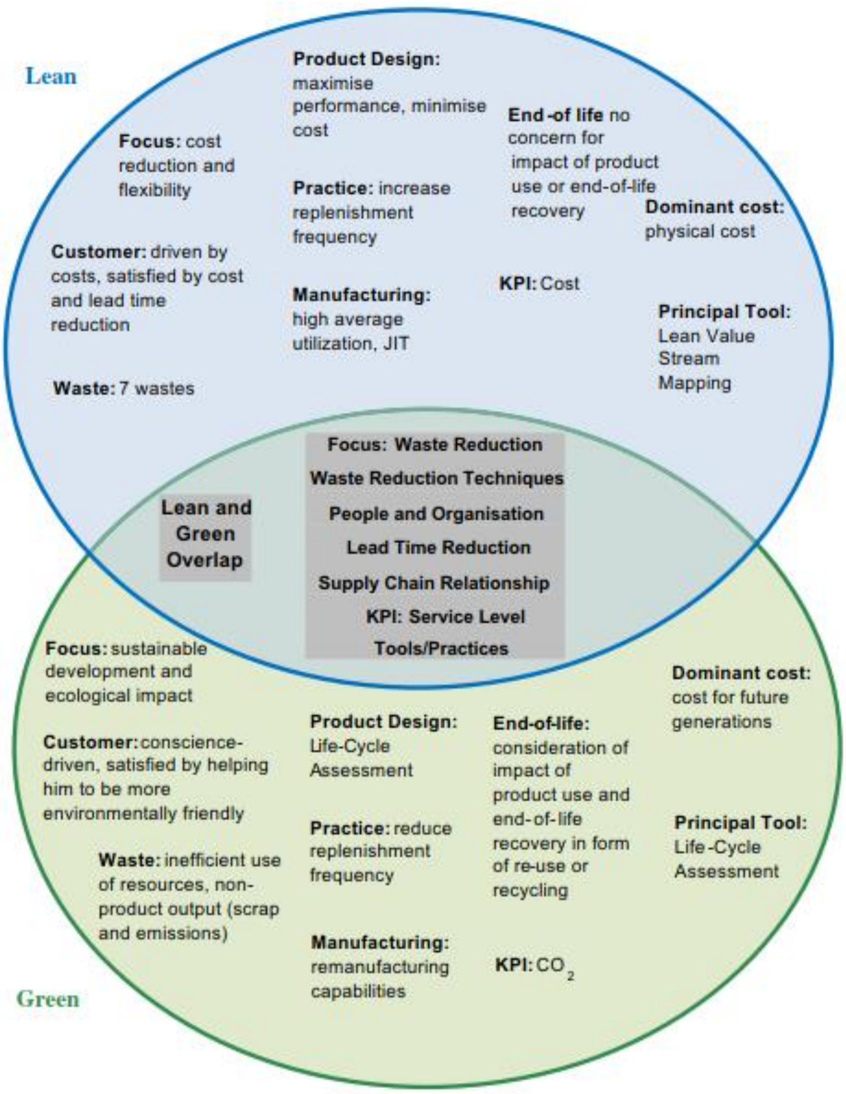

Figure 2.1: General overview of the complementary and contradicting areas between LM and GM (Dües *et al*., 2013)

Dües *et al.* (2013) highlighted the synergies (Bergmiller, Mccright and Florida, 2009b) and divergencies (King and Lenox, 2001) between LM and GM. The similarities include the focus of both LM and GM on waste reduction (Torielli *et al.*, 2010; Pampanelli *et al.*, 2011; Bashkite and Karaulova, 2012; Cabral *et al.*, 2012; Chahal, 2012) by applying various techniques and tools such as VSM and Life Cycle Assessment (LCA) (Bergmiller and McCright, 2009; Johansson and Winroth, 2009; Winroth and Johansson, 2009; Parveen *et al.*, 2011). Furthermore, both methodologies involve people (Pampanelli *et al.*, 2011; Bashkite and Karaulova, 2012), organisations, value and supply chain relationships (Florida, 1996; Simpson and Power, 2005; Winroth and Johansson, 2009), and both focus on lead time reduction (Pampanelli *et al.*, 2011; Parveen *et al.*, 2011).

LM and GM show differences in various areas. Although both methodologies focus on waste reduction, they target different types of waste (Bashkite and Karaulova, 2012). Unlike GM, LM is not concerned with product end-of-life because Lean customers are not so concerned with environmental performance (Bashkite and Karaulova, 2012). Instead, LM designs products to maximise performance while minimising cost. On the other hand, GM is concerned about product end-of-life issues (Florida, 1996; Bashkite and Karaulova, 2012); hence, it employs techniques such as LCA to minimise environmental damage (Hall, 2009). It was discussed that LM focuses on cost and flexibility while GM is concerned with improving environmental performance. In addition, Lean customers are more concerned about the cost of the product (Bashkite and Karaulova, 2012), which, together with lead time reduction, satisfies these customers. Hence, the products are designed to improve performance and reduce costs (Florida, 1996; Taubitz, 2010), making cost a key performance indicator. On the other hand, Green customers are interested more in environmentally friendly processes and products (Florida, 1996; Carvalho *et al.*, 2010; Bashkite and Karaulova, 2012); hence, GM is concerned with eliminating environmental waste (Duarte *et al.*, 2011). Therefore, LCA is deployed to monitor the environmental impact of the products in their entire lifetime (Johansson and Winroth, 2009). In LM, the process is based on JIT (Rothenberg *et al*., 2001; Zhu and Sarkis, 2004), thereby increasing the frequency of replenishment, resulting in increased emissions (Rothenberg *et al.*, 2001; Bashkite and Karaulova, 2012). GM reduces the replenishment frequency (Florida, 1996), thereby reducing greenhouse gas emissions. Hence, there is a need for trade-offs between JIT and greenhouse gas emissions (Rothenberg *et al.*, 2001; Sawhney *et al.*, 2007; Mollenkopf *et al.*, 2010). The dominant cost in LM is physical costs, and VSM is the principal tool, while in GM, the dominant cost is the cost to future generations, and LCA is used as the principal tool (Johansson and Winroth, 2009).

2.5 Comparison between LM and GM

To successfully implement Lean-Green without missing the possible synergies or neglecting the important trade-offs that may arise, organisations must understand the complementary and conflicting natures of the two methods (Hallam and Contreras, 2016a). Most researchers have pointed out that the pattern obtained by Dües *et al*. (2013) is still apparent even today; hence, the student used their classification structure to highlight the similarity to the post-2013 findings by referencing the more recent authors supporting these findings. These areas are shown at the top of Table 2.1 in items 1-13, with the more recent collaborations shown in the last column. However, we also found areas that Dües *et al*. (2013) did not seem to have covered extensively, and these have been added to the bottom of Table 2.1, thus, items 14-20. The extended areas are covered under the topic: philosophy focus; product and/or process focus; sustainability contribution, value; improvement process; profitability and competitiveness; and the most common practices. Table 2.1 shows this comparison of the attributes of LM and GM.

Table 2-1: Comparison of LM and GM: distinctive attributes

LM and GM attributes	LM	GM	Supporting reference
1. Waste perception	7 + 1 Lean wastes	Environmental wastes	(Abdullah *et al.*, 2014; Garza-reyes *et al.*, 2014; Pampanelli, *et al.*, 2014; Prasad and Sharma, 2014; Wiese *et al.*, 2015; Bortolini *et al.*, 2016; Hallam and Contreras, 2016; Lerher *et al.*, 2016 ; Wu and Wang, 2016; Logesh *et al.*, 2017; Zekhnini *et al.*, 2021)
2. Customer attention	Customers are satisfied with the cost and lead time	Customers are satisfied with the environmental management	(Pampanelli *et al.*, 2014; Bortolini *et al.*, 2016; Duarte and Cruz-Machado, 2018; Coutinho *et al.*, 2019; Harisekar, 2021; Sharma *et al.*, 2021)
3. End of life approach	No concern about end-of-life products	Concerned about products end of life	(Campos and Vazquez-brust, 2016; Lerher *et al.*, 2016; Harisekar, 2021)
4. Product design focus	Maximise performance, minimise cost	Uses LCA to decrease waste and minimise environmental impacts	(Garza-reyes *et al.*, 2014; Hallam and Contreras, 2016; Thanki *et al.*, 2016; Dawood and Abdullah, 2017; Moro *et al.*, 2019)
5. Focus of the concept	Focuses mainly on diminishing cost	Focuses on improving sustainable and environmental performance	(Pampanelli *et al.*, 2014; Hallam and Contreras, 2016; Rad and Azizi, 2021)
6. Practice strategy	It aims to increase the replenishment frequencies by decreasing lot-sizes	The objective is to decrease the replenishment frequencies	(Bortolini *et al.*, 2016; Campos and Vazquez-brust, 2016; Harisekar, 2021)
7. Supply chain management	Customers are involved, and there is a close relationship with suppliers	Suppliers are involved in improved environmental performance	(Galeazzo *et al.*, 2014; Sabadka, 2014; Hallam and Contreras, 2016; Wu and Wang, 2016; Duarte and Cruz-Machado, 2018; Bhattacharya *et al.*, 2019; Kumar and Rodrigues, 2020; Suhardini and Hadiwidjojo, 2021)
8. Lead time approach	Seeks to reduce lead time	Seeks to improve lead time	(Hallam and Contreras, 2016; Thanki *et al.*, 2016; Basha *et al.*, 2020; Suhardini and Hadiwidjojo, 2021)
9. Waste reduction techniques	Applies various techniques to reduce waste.	Applies various techniques. 3R is the	(Johansson and Sundin, 2014; Garza-Reyes, 2015; Bortolini *et al.*, 2016; Florescu and Barabaş, 2018)

	The most common and principal Lean practice is VSM	most common. LCA is the principal tool.	
10. Employee involvement	Employees are involved in continuous improvement	Employees are involved in implementing GM for enhanced environmental performance	(Abdullah *et al.*, 2014; Johansson and Sundin, 2014; Sabadka, 2014; Lerher *et al.*, 2016; Duarte and Cruz-Machado, 2018; Bhattacharya *et al.*, 2019)
11. Leadership and strategic planning (organisation)	Management should be involved and show commitment and provide resources, set clear strategies required for the successful implementation	The successful implementation of GM requires the support, involvement and commitment of the top management in setting clear strategies	(Abdullah *et al.*, 2014; Szymanska-Bralkowska and Malinowska, 2017)
12. Gas emissions	Increases the emissions due to increased transportation necessitated by JIT	It aims to reduce all forms of emissions	(Bortolini *et al.*, 2016; Campos and Vazquez-brust, 2016; Hallam and Contreras, 2016; Jbira *et al.*, 2020)
13. KPI/s	Cost and flexibility	CO_2	(Florescu and Barabaş, 2018; Harisekar, 2021)
14. Philosophy focus	Long-term thinking	Long-term thinking	(Sabadka, 2014; Duarte and Cruz-Machado, 2018)
15. Product and/or process focus	Focuses mainly on processes	Products and processes focus	(Sabadka, 2014; Duarte and Cruz-Machado, 2018)
16. Sustainability contribution	Affects people and profit	Affects the planet	(Pampanelli *et al.*, 2015; Pampanelli *et al.*, 2016)
17. Value	Value is created through the generation of products that attract customers due to low costs	Value is associated with satisfying customers by creating products in an environmentally friendly manner	(Pampanelli, 2015; Bortolini *et al.*, 2016)

18. Improvement process	Focus on continuous improvement through the elimination of Lean waste	Focus on continuous improvement through the elimination of environmental waste	(Fercoq *et al.*, 2016; Bhattacharya *et al.*, 2019)
19. Profitability and competitiveness	Reduction of waste makes the companies more profitable	Competitiveness is attained through the decrease in environmental damage	(Kaswan *et al.*, 2020)
20. Most common practices	VSM	3R	Study results

2.6 Lean-Green barriers

Organisations have to understand the barriers they are likely to face in trying to attain improvements in sustainable performance and develop ways to tackle them. Several studies have been done to identify the Lean and Green barriers; for example, Cherrafi *et al.* (2017b) noted a lack of government support and lack of awareness. The study by Sarhan and Fox (2013) highlighted a lack of awareness, lack of top management commitment, and organisational culture as the three main barriers. Abu *et al.* (2019) indicated that barriers to Lean organisations are related to the activities of employees, including lack of knowledge, lack of labour resources, and resistance to change.

Lean-Green barriers can be classified as either external or internal barriers, and such classifications help decision makers in organisations, governments, and other stakeholders to tackle them efficiently and effectively (Jabbour *et al.*, 2016). In this study, the Lean-Green barriers were identified from the literature and are shown in Table 2.2. Internal and external barriers are latent variables, and they are measured using the items that were found in the literature. These items are represented by IB1 to IB10 for internal barriers and EB1 to EB7 for external barriers. The description of each item is also highlighted in Table 2.2.

Table 2.2: Internal and external barriers

Barrier Classification		Barriers	Description	Authors
Internal Barriers (IB)	IB1	Lack of top management commitment	The commitment of managers and support is important as they provide resources and knowledge, amongst others.	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12, 13, 14, 15
	IB2	Lack of awareness/ information	Inadequate information on available technology options and limited access to information dissemination.	1; 2; 6; 7; 8; 9; 10; 12; 13
	IB3	Lack of	Organisations' ability to attain	3; 5; 7; 9; 13

		organisational resources	improvements in organisational performance is hampered by a lack of technical and human resources.	
	IB4	Ineffective technology	The latest technologies are required to meet the requirements for proper Lean-Green adoption.	1; 2; 4; 5; 7; 8; 9; 12; 14;15; 16
	IB5	Lack of training and education	A lack of appropriately training programs may impede familiarising employees with relevant skills.	1; 2; 4; 6; 8; 9; 10; 12; 16
	IB6	Resistance to change	Changing workers' mindsets from the traditional way of working is difficult. As a result, it is necessary to identify the employees who are hesitant to embrace new technologies and provide training to them, emphasising the benefits of Lean-Green.	1; 9; 10; 11; 15; 16
	IB7	Fear of failure	Involves the fear of failure to attain intended improvements, leading to financial losses, or the fear of product failure, resulting in a loss of competitive advantage.	6; 10; 11; 12
	IB8	Poor quality of human resources	Employees have been identified as one of the most critical resources for any organisation in its quest for success.	2; 4; 5; 6; 9; 10; 12; 14; 15
	IB9	Company culture	Organisations are unwilling to leave the traditional way of operation and methodologies that have worked enough for them.	1; 2; 3; 4; 8; 9; 10
	IB10	Financial constraints	Funds must be invested to reap economic, social, and environmental benefits.	1; 2; 4; 6; 7; 8; 9; 10; 12; 15; 16
External Barriers (EB)	EB1	Weak legislation	Legislation and regulation are essential tools for the suitable governance of businesses and the environment in which they operate. Environmental laws and regulations offer a critical framework within which organisations must operate.	3; 7
	EB2	Low enforcement of laws and corruption	Ineffective adoption of laws, corruption, and an insufficient monitoring mechanism.	7
	EB3	Low public pressure	The absence of pressure from key social actors such as communities, the media,	7

			non-governmental organisations, banks, insurance companies, or politicians.	
	EB4	Uncertain future legislation	Future legislation may have unanticipated consequences for large investments in newer technologies.	7; 9; 16
	EB5	Lack of government support	Many companies, especially SMEs, find it challenging to generate large initial capital and, as a result, require government assistance.	1; 6; 8; 10; 12; 13; 14
	EB6	Low customer demand	Due to price-sensitive and uninformed customers, there is a low demand for environmentally friendly products and processes.	4; 6; 7; 9; 12; 13
	EB7	Uncertain benefits	Uncertainty about the benefits that can be obtained after making large investments in newer technologies.	2; 4; 7; 9; 11

Authors : 1 - Singh *et al*. (2020); 2 - Kumar *et al*. (2015); 3 - Mittal *et al*. (2016); 4 - Kumar *et al*. (2016); 5 - Sindhwani *et al.* (2020); 6 - Kumar *et al.* (2016); 7 - Mittal and Sangwan (2014); 8 -Machingura and Zimwara (2020); 9 - Osman *et al.* (2020), 10 - Cherrafi *et al.* (2017); 11- Abolhassani *et al.* (2016); 12- Kaur *et al.* (2017); 13 - Mathiyazhagan *et al.* (2017); 14 - Luthra *et al.* (2011); 15 - Narkhede *et al.* (2020); 16 - Jabbour *et al.* (2016)

The literature has demonstrated what LM and GM studies have been conducted. This shows that there are still opportunities for research in this area, especially on LM and GM integration. Also, the literature has demonstrated how developing nations are progressing on LM and GM adoption. Thus, this shows that there are some questions which are yet to be answered and this research aims to answer some of these questions as identified in section 1.4. To answer these questions qualitative and quantitative methods are used, for instance, SEM will examine the impact of Lean-Green on organisational performance.

2.7 Research gap

The research starts by examining the complementary and conflicting areas between LM and GM. Although Dües *et al.* (2013) did a similar study, this research seeks to expand this knowledge, but in this case, focusing on papers published post-2013. Thus, a comparison was made with the results by Dües *et al.* (2013), which focused on papers published pre-2013. Furthermore, the research investigates the impact of Lean-Green on operational and environmental performance. Most previous studies focused on the impact of either LM or GM on the performance of organisations (Ganiyu, 2021; Hassan and Jaaron; 2021; Rehman and Yu, 2021; Sharma *et al.*, 2021; Singh *et al.*, 2022, Saini and Singh, 2022). However, this research expands this knowledge by examining the effect of combined Lean-Green on the performance of organisations. The only study that considered the impact of Lean-Green on organisational performance was done by Inman and Green (2018) in US manufacturing companies. However, the limitation of that study is that it did not compare the impact of simultaneously implementing LM and GM with individual implementation. This would have shown if integration LM and GM yields better results than individual implementation, thus, making the organisations decide whether to integrate Lean and Green or implement one of the methodologies.

Also, the study examined the mediatory role of environmental performance on the relationship between Lean-Green and socio-economic performance. Most studies focused on the individual implementation of LM and GM and their impact on sustainable performance (Antony *et al*., 2022). This research extends the current knowledge by investigating the impact of Lean-Green on 3BL. Additionally, the research demonstrates the impact of improving environmental performance on economic and social performance improvements. Thus, exploring how improvements in environmental performance can make organisations improve their economic and social performances leading to enhanced sustainable performances.

The impact of Lean-Green barriers on hindering organisations from attaining improved 3BL was highlighted in this study. To the best knowledge of the student, no research has been conducted that developed a Lean-Green structural equation model to assess the relationships between Lean-Green barriers that are encountered post implementation and enhanced sustainable performance. The only study that examined the relationship between internal and external barriers to organisational performance was done by Jabbour *et al.* (2016). However, the research was on green operational practices, not Lean-Green Manufacturing, and did not consider the effect on sustainable performance.

2.8 Chapter conclusion

This chapter discusses the literature on LM, GM and Lean-Green, and their implementation in developing countries, including Zimbabwe. In addition, the synergies and divergencies between LM and GM were pointed out. The barriers to the implementation of Lean-Green Manufacturing were also identified and discussed in detail.

Chapter 3: Methodology

3.1 Introduction

This chapter discusses the methodologies that were used in this research. It is important to emphasise that two research methodologies will be presented in this section, one is qualitative and the other is quantitative. The research questions needed to be addressed by different approaches; hence a mixed method was used. The first research question was addressed using the qualitative method and the other questions were answered using the quantitative method. The qualitative method was done using the Systematic Literature Review (SLR), which employed the Population, Intervention, Comparison, Outcome (PICO) technique and coding with ATLAS.ti. Thus, allowing the author to determine the complementary and conflicting nature of Lean Manufacturing (LM) and Green Manufacturing (GM), focusing on papers published post-2013. Thus, expanding the work done by Dües *et al*. (2013). The quantitative method used Structural Equation Modelling (SEM) to analyse the data collected through a survey and explore the impact of Lean-Green on organisational performance. Additionally, the data from the survey was used to analyse the extent to which internal and external Lean-Green barriers impede organisations from improving their sustainable performance. The data was analysed using Statistical Package for Social Sciences (SPSS) 26 and SMART PLS 3. Finally, the results obtained from the qualitative and quantitative methodologies were compared, and conclusions were drawn from them.

3.2 Qualitative method

3.2.1 SLR method

This study used SLR to find existing information about the complementary and conflicting nature between LM and GM. SLR helps in identifying the gaps in extant studies and provides a crucial overview of these studies (Bhattacharya *et al*., 2019). It is a transparent, comprehensive, replicable and explicit method that ensures the process is conducted accurately (Farias *et al.*, 2019; Siegel *et al.*, 2019). SLR identifies, evaluates, and synthesises the existing recorded work done by other scholars, practitioners, and researchers (Siegel *et al.*, 2019). It has gained popularity in various research fields as it gives a reliable means to get a complete overview of the research themes (Farias *et al.*, 2019). SLR has five phases: (a) question formulation, (b) study location, (c) evaluating and selecting appropriate studies, (d) synthesis and analysis, and (e) using the obtained results (Caiado *et al*., 2017; Abualfaraa *et al.*, 2020).

In order to enhance the quality of the review, the PICO format was used. In evidence-based research, PICO is used to formulate and answer questions (Scells *et al.*, 2017). In this case, the population is the organisations; the intervention is the implementation of Lean-Green; a comparison was done with studies conducted before 2013 leading to the paper by Dües *et al*. (2013); and the outcome is the organisational performance. An important step in the PICO format is determining the synonyms using the PICO logic grid (Aromataris and Riitano, 2014; Vrchota *et al*., 2020). These synonyms are shown in Table 3.1.

Table 3-1: The PICO logic grid

	Population	Intervention	Comparison	Outcome
Synonyms	Organisations Companies Firms	Green manufacturing Environmental manufacturing Eco/ecological manufacturing Clean manufacturing Low carbon manufacturing	-	Organisational performance Operational performance Sustainability Environmental performance Ecological performance

During the search process, Lean was used as a single term as done by Kelendar *et al.* (2020), while the synonyms for Green were adopted from Vrchota *et al*. (2020). The search was limited to keywords such as LM, GM, Green, Lean-Green, Lean and cleaner production. Keywords identification allowed room for an unbiased and comprehensive review (Caiado *et al.*, 2017). The articles used were identified from Scopus, Web of Science, and Google Scholar databases, using the search strategy in Table 3.2.

Table 3-2: Search strategy

	PICO tool	Search terms
1.	P	"Organi?ation*" OR "Compan*" OR "firm*"
2.	I	("manufacturing" OR "process*" OR "operation*" OR "technolog*" AND ("Green" OR "Clean" OR "Environmental" OR "low carbon" OR "Eco" OR "Ecological" OR "Clean")
3.	C	-
4.	O	("performance*") AND ("organi?ation*" OR "operation*, OR "sustainab*"
	Query	2 AND 3 AND 4

2921 papers were identified at the initial stage. Duplicate screening permitted for the exclusion of 2382 articles and 97 articles were removed because they had no authors' names. Language exclusion allowed for the removal of 73 articles, while the non-availability of full text for download caused the elimination of 101 articles. The next phase of inclusion and exclusion was done using the PICO format (Kelendar *et al.*, 2020), as shown in Table 3.3. The 268 remaining articles were screened using the abstracts and titles, which caused 53 articles to be removed. Finally, the full-text analysis method permitted 74 articles to be excluded. The remaining 141 articles matched the selection criteria and were used in this study. Journal articles, conference publications and thesis published between 2014 and 2021 were considered. Figure 3.1 shows the methodology for the article selection.

Table 3-3: PICO inclusion and exclusion criterion

PICO	Included	Excluded
Population	All papers focusing on the integration of Lean-Green in the manufacturing industry.	All papers focusing on Lean-Green in other sectors that are not manufacturing.
Intervention	Implementation of Lean-Green.	Implementation of LM and GM separately.
Comparison	Lean-Green implementation post-2013.	Lean-Green implementation pre-2013.
Outcome	Impact of Lean-Green on operational and environmental performance.	-

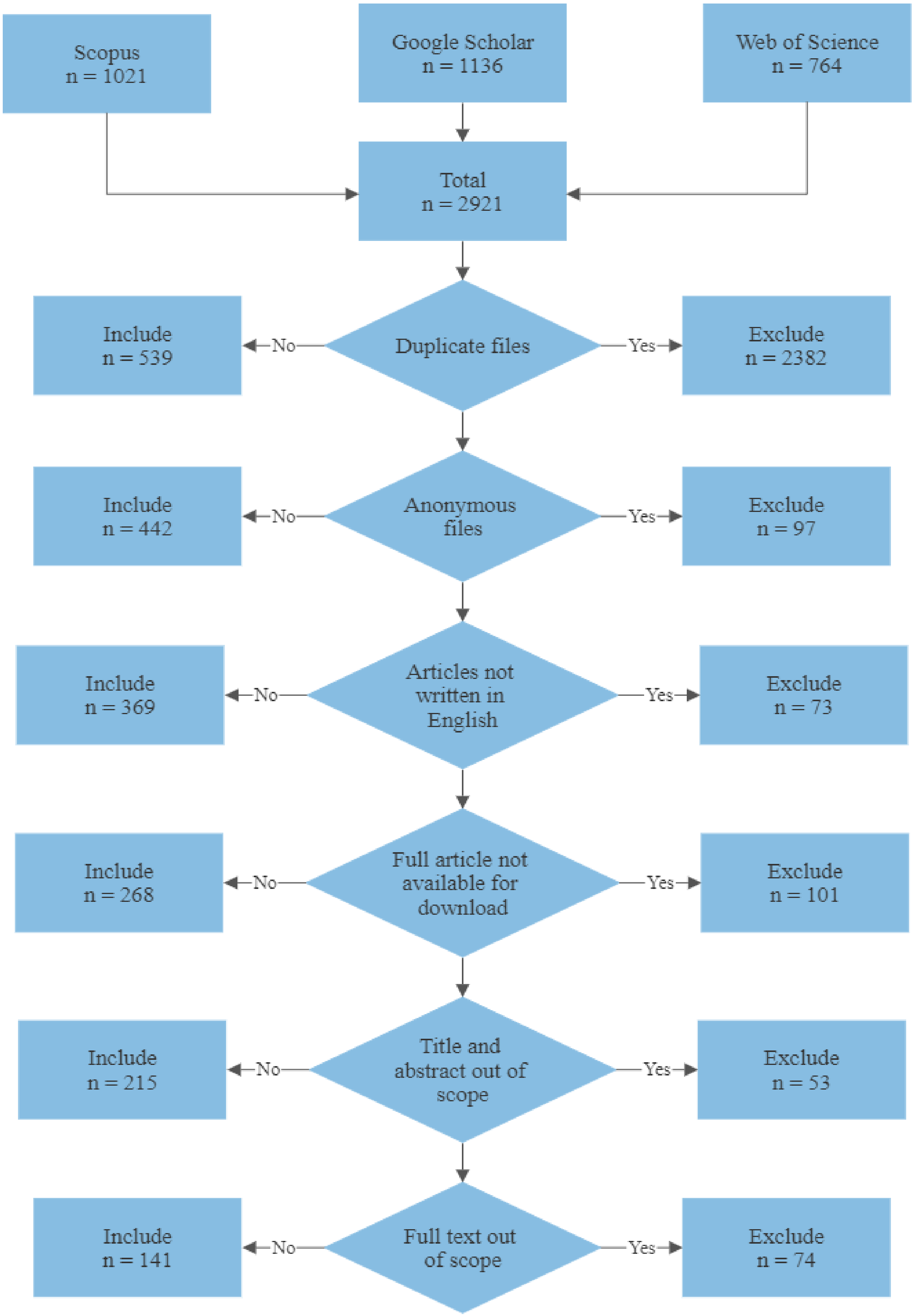

Figure 3.1: Article selection process

The selected articles were analysed using ATLAS.ti 22 to identify the themes and their relationships. ATLAS.ti was considered appropriate for this research to interpret, classify, and summarise the data gathered (Moshood *et al.*, 2020; Moshood *et al.*, 2021). One advantage of using ATLAS.ti 22 is that it provides quick access to articles based on keywords, relationships, subjects, and themes (Moshood *et al.*, 2020; Moshood *et al.*, 2021b). Open coding and in-vivo coding were used to identify keywords and important information. The first-order coding was accomplished by identifying keywords associated with LM, GM, environmental performance, operational performance, barriers, Critical Success Factors (CSFs), and drivers. First-order codes were assigned to terms like Just in Time (JIT), Reduce, Recycle and Reuse (3R), cost reduction, top management support, and financial barrier. Higher-level coding was used to aggregate these codes into groups. 137 first-order codes were identified, and these were placed into 11 groups. The group codes were further refined into 8 groups, namely: operational performance, environmental performance, barriers, CSF, drivers, integration with other techniques, synergies, and divergences.

This section focuses on a literature review of the papers published post-2013. PICO and ATLAS.ti coding were used to analyse these papers. The following section looks at the quantitative method that was used in SEM as shown in chapter 4.

3.3 Quantitative method

The method discusses the data collection process from the Zimbabwe manufacturing industry. Zimbabwe is a developing country that is currently facing many economic challenges. Hence, many organisations worry more about improving their profits compared to implementing methodologies such as LM and GM, which also requires resources. This study, therefore, seeks to enlighten these organisations that their goal of improving profit can be attained through investing in Lean-Green.

The method starts by developing the questionnaire through adapting questions from the literature, followed by data collection, data cleaning, data entry, and data analysis process. SEM was used to analyse the data and develop research models.

3.3.1 Development of the questionnaire

A self-administration questionnaire was developed to assess the impact of Lean-Green implementation on organisational and sustainable performance of the manufacturing companies. To enhance the validity of the questionnaire, it is recommended to adopt questions from the literature (Murillo-Luna *et al.*, 2011; Huo *et al.*, 2019; Shashi *et al.*, 2019). The questions were extracted from (Nawanir *et al.*, 2013; Godinho Filho *et al.*, 2016; Inman and Green, 2018; Iranmanesh *et al.*, 2019; Yadav *et al.*, 2019). The questionnaire contained five sections. Section A focused on the general information about the company. Section B outlined the level of LM adoption by the manufacturing companies. Section C covered the level of GM adoption. Section D focused on the impact of implementing selected Lean-Green practices on environmental, social, economic, and operational performance. Section E outlined the internal and external Lean-Green barriers that impede organisations from attaining improvements in sustainable development. A five-point Likert scale was used with ratings; 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree. These ratings specified the degree of agreement or disagreement with the given statements.

3.3.1.1 Content validity

Content validity is the technique that is used to ensure that the measures adequately quantify the various concepts that they are supposed to test and it depends on how good the researchers cover the content of the variable under investigation (Luthra *et al*., 2015). In this research, the content validity was based on an exhaustive literature search and expert consultation as done by Govindan *et al*. (2015). The questionnaire was pretested by sending it to experts from the industry and academia to improve its validity (Murillo-Luna *et al.*, 2011; Jabbour *et al.*, 2013; Huo *et al.*, 2019; Cherrafi *et al.*, 2018; Belhadi *et al.*, 2020). As a result, some questions were removed, others were modified, and some were added. The questions that were finally developed were used for data collection.

3.3.2 Data collection

The questionnaires were administered to the Zimbabwean manufacturing companies using two methods. The first method was the drop and pick method. 453 hard copies of the questionnaires were distributed through hand delivery. Initially, 209 questionnaires were returned, out of which 11 were considered invalid and discarded; hence, 198 valid questionnaires were used from this first method. The second method was an online survey that utilised a google form where a link to the questionnaire was sent to the potential respondents. 329 invitations were sent through an online survey, and 104 valid responses were obtained. To increase the response rate, several follow-ups were made through emails, telephone calls (Jabbour *et al.*, 2013; Huo *et al*. 2019; Belhadi *et al.*, 2020) and WhatsApp messaging (Diabat and Govindan, 2011). Personnel in higher positions such as operations, quality, and environmental managers were invited to participate in the study. The manufacturing, Safety, Health, and Environment (SHE) and quality departments were chosen because these are the areas that are well versed with LM and GM issues (Jabbour *et al.*, 2013). Also, multiple respondents from the same organisation were invited to participate in the survey (Longoni and Cagliano, 2015), ensuring that the data is unbiased. The responses were kept anonymous with a high level of confidentiality (Murillo-Luna *et al*., 2011). The total number of valid responses was 302, giving an overall response rate of 38.6 %. The response rate is high enough considering the questionnaire was completed by manufacturing personnel who are usually busy, as also acknowledged by Kuo and Lin (2020).

3.3.3 Sampling methods

This study utilises both probability and non-probability sampling methods which are expert sampling and random sampling. Expert sampling was used during the questionnaire development process. Random sampling was used during the data collection process, where respondents from the manufacturing industry were randomly selected to complete the questionnaire.

3.3.3.1 Expert sampling

Expert sampling is a technique for collecting the opinions of people who are experts in a particular field. It was used to identify Lean-Green experts from academia and industry who are familiar with LM and GM issues (Etikan and Bala, 2017). Experts were consulted during the questionnaire development process, and their comments and suggestion were considered. This improved the content validity of the survey instrument. Content validity is evaluated by how clearly and effectively the research covers and explains the variable(s) under inquiry within any given study (Luthra *et al*., 2015). Hence, for the questionnaire to have content validity, all variables must be appropriately questioned (Del Greco *et al*., 1987).

3.3.3.2 Random sampling

The survey was conducted in the Zimbabwean manufacturing industry with a sampling frame that include food and beverage, chemicals and petrochemicals, plastic and rubber, pharmaceutical, agrochemical, wood and furniture, electronics and electrical, fertilizer, textiles, leather, paper, ceramic, steel, tiles and bricks, automotive, battery, foundry, tobacco and glass industries. However, no responses were obtained from the tobacco and glass industries; hence, they were not included in the study.

To collect data from the specified sample frame, random sampling was used. Random sampling is a probability sampling strategy in which each member of the population has an equal chance of being chosen (Etikan and Bala, 2017; Berndt, 2020). Consequently, random sampling was used in this study. As a result, no pattern was used during data collection, and samples were chosen randomly based on the author’s accessibility owing to Covid-19 restrictions.

3.3.4 Data cleaning and data entry

After the data collection process, data cleaning process was done. This is a process of eliminating erroneously filled, replica, and incomplete data. Data cleaning is an important step prior to the data entry and analysis process. The student had to clean the data to eliminate invalid data that would affect the study results. Each questionnaire was evaluated, and responses that displayed specific patterns, such as diagonal patterns, were deemed ineligible and were eliminated. Additionally, questionnaires containing the same response for all the questions were eliminated. Furthermore, answers with a large amount of missing data were deemed invalid and were discarded. SPSS v 26 was used for data entry and the data was converted to Microsoft Excel in preparation for SMART PLS.

3.3.5 Data analysis methods

Two statistical software were deployed for the data analysis process. These are SPSS and SMART PLS.

3.3.5.1 Descriptive statistics

Data collected from the questions in Section A was analysed using descriptive statistics. Descriptive statistics helps in summarising and interpreting the data. The frequencies and percentages were determined as shown in 4.3 to 4.6.

3.3.6 SMART PLS analysis

Smart PLS is one of the well-known methods for Partial Least Squares Structural Equation Modelling (PLS-SEM). Since its introduction in 2005, the program's popularity has increased because researchers can use it for free for sample sizes not exceeding 100, and because it offers a user-friendly interface and comprehensive reporting tools (Wong, 2013). SEM is a multivariate data analysis technique used to assess models by investigating the relationships between variables. SEM uses unobservable, difficult to measure latent variables, making it the best method for solving research issues.

SEM has two submodels; the outer and inner models. The outer model describes the relationships between the latent variables and their observed indicators, while the inner model describes the relationships between the independent and dependent latent variables. SEM can be done in a variety of ways: The first strategy uses the popular Covariance-Based SEM (CB-SEM) which is ideal for large samples and normally distributed data (Wong, 2013). However, it can be difficult to find a data set that meets these criteria, as many researchers acknowledge. The second strategy uses PLS-SEM, which makes no assumptions about the distribution of the data. Thus, PLS-SEM becomes a good substitute for CB-SEM (Wong, 2013).

This research used Smart PLS to run the PLS algorithm, and perform bootstrapping, blindfolding, and Importance-Performance Map Analysis (IPMA). In addition, smart PLS was used to assess and validate the proposed relationships between the variables. PLS-SEM is more applicable when testing hypotheses and relationships that contain second-order latent variables (Green *et al.*, 2018).

3.3.6.1 PLS algorithm

PLS algorithm was the initial method to be performed by using SMART PLS 3. During the model run procedure, 300 runs were performed (Hair *et al.*, 2017). The results obtained from the PLS-SEM include path coefficients, cross loadings, outer loadings, Variance Inflation Factor (VIF), Cronbach's alpha, composite reliability, coefficient for determination (R^2), effect size (f^2), Average Variance Extracted (AVE), Fornell-Lacker criterion and Heterotrait Monotrait (HTMT) ratio. AVE and outer loadings are used for assessing convergent validity, while HTMT, cross loadings and Fornell-Lacker criterion are essential for evaluating the discriminant validity. Additionally, Cronbach's alpha values and composite reliability are useful in assessing the reliability and internal consistency of the measurement model. The interpretation of the PLS-SEM is given in detail in the results section.

3.3.6.2 Bootstrapping

Bootstrapping is re-sampling method used to determination the significance of the path coefficients on the structural model (Jabbour *et al.*, 2013, 2016; Famiyeh *et al.*, 2018; Ghobakhloo *et al.*, 2018). The execution of the bootstrap algorithm enabled the evaluation of the quality of the structural model as recommended by Green *et al.* (2018). During the analysis, the bootstrap resampling method with 5000 runs were used (Hair *et al.*, 2017; Ghobakhloo *et al.*, 2018). Therefore, the significance of the model's paths was determined using t-statistics and p-values at 5% confidence interval.

3.3.6.3 Blindfolding

Blindfolding procedure was used to obtain the predictive relevance of the model. The Stone-Geisser's Q^2 value assesses how accurate the model is and shows its predictive relevance (Famiyeh and Adaku, 2018; Maware and Adetunji, 2019b).

3.3.6.4 Importance Performance Map Analysis

The IPMA was conducted using SMART PLS 3 to determine the importance and performance of the predecessor latent variable. This is done to identify those predecessor latent variables with high importance but low performance so that they can be improved.

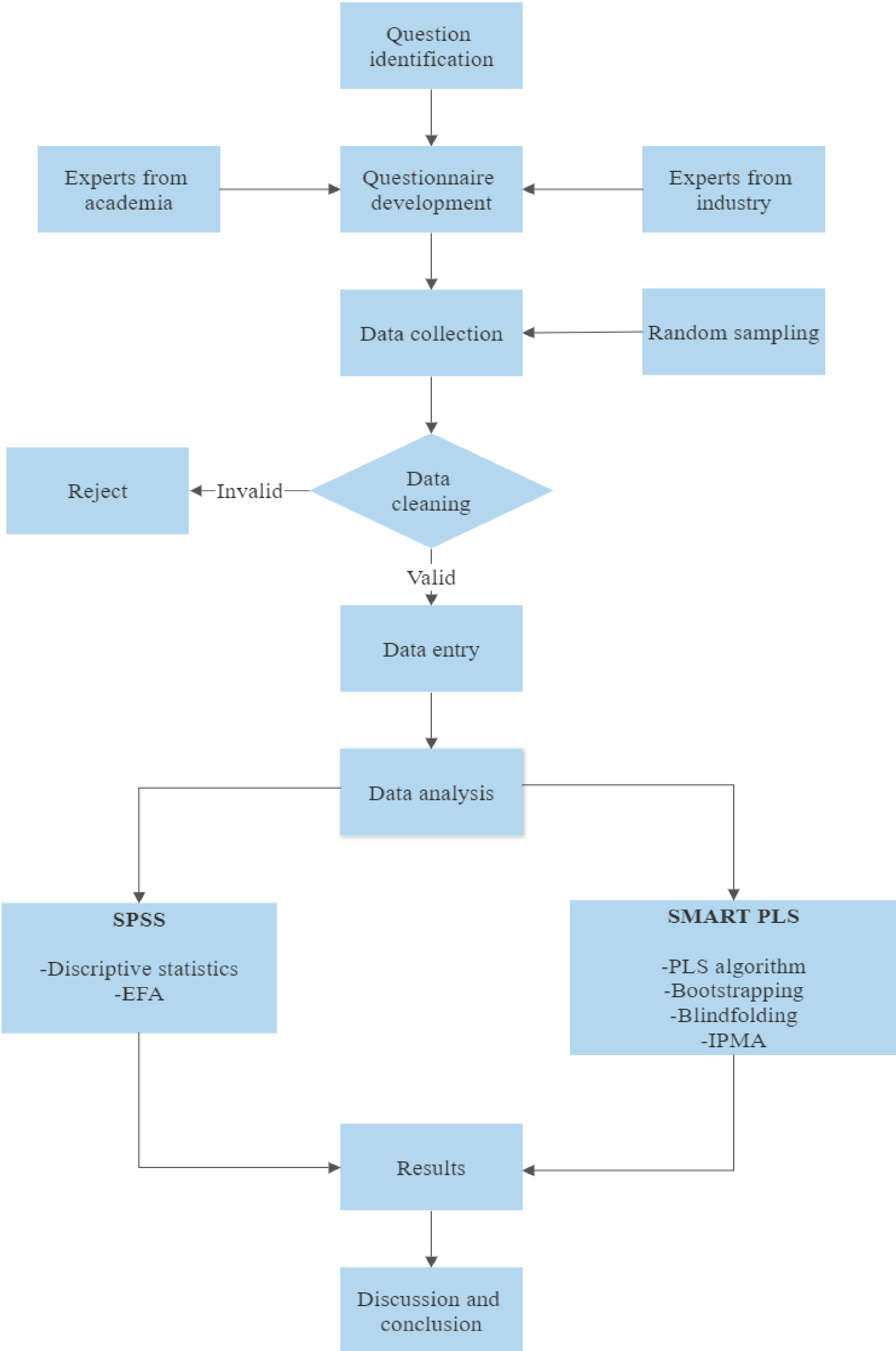

Figure 3.2: Methodology Flow-chart

3.4 Chapter conclusion

This chapter highlights the mixed methods used for this research. It illustrates the use of the qualitative method in determining the complementary and contradictory areas of LM and GM. It also explores how the quantitative method was used in developing and analysing the research models.

Chapter 4: Results

4.1 Introduction

This chapter starts by presenting the results of the qualitative method followed by those from the quantitative approach. The relationship between the findings of the two methods are compared, and conclusions are made. The overlaps for the complementary and conflicting nature of Lean Manufacturing (LM) and Green Manufacturing (GM) were determined. Also, the impact of Lean-Green on operational and environmental performance was illustrated. Furthermore, the mediatory role of environmental performance on the relationship between Lean-Green and socio-economic performances was indicated. Lastly, the impact of Lean-Green barriers towards the improvements in sustainable development was outlined.

4.2 Complementary and conflicting areas between LM and GM

4.2.1 Introduction

As local regulatory authorities begin to demand environmental friendliness from manufacturers, many are battling to be both profitable and ecologically compliant due to the strain of global competitiveness and its local consequences on manufacturing enterprises. From a literature viewpoint, this part aims to evaluate the impact of combining Lean and Green practices on organisational performance and provide ways to promote synergies while limiting mutually harmful consequences. Implementing Green techniques is not necessarily complementary to Lean, according to the literature, but the nature of this relationship and the extent of their interaction have not been completely explored. This section extends the present knowledge necessitated by the growth in Lean-Green interest and research. A systematic search was done to identify the Lean-Green articles from Scopus, Web of Science, and Google Scholar databases. To create and answer the research questions, Population, Intervention, Comparison, Outcome (PICO) format was used. Research themes were developed by analysing 141 papers using ATLAS.ti version 22. According to the findings, LM and GM have strong synergies and can be combined to enhance organisational performance. As a result, organisations should consider their simultaneous implementations to maximise benefits. However, conflicting areas exist between LM and GM, necessitating trade-offs.

4.2.2 Brief background

Dües *et al*. (2013) highlighted the integration of LM and GM and outlined a fully fleshed Lean-Green overlap. In doing so, the papers written pre-2013 were used, and this research acknowledges this well-written paper. However, this research extends this knowledge by answering the following research questions.

RQ1. How complementary or contradictory are the impacts of implementing Lean and Green techniques in manufacturing organisations?

RQ2: Is the pattern obtained pre-2013 by Dües *et al*. (2013) similar or different from that obtained post-2013?

4.2.3 Findings

4.2.3.1 Demographic characteristics

Lean-Green Manufacturing is a method that seeks to integrate LM and GM practices to improve organisational performance. The integration is motivated by the fact that both methods focus on reducing manufacturing waste. Figure 4.1 shows the Lean and Green practices identified from the papers used. The most common Green practice is 3R while the most common Lean practice is Value Stream Mapping (VSM).

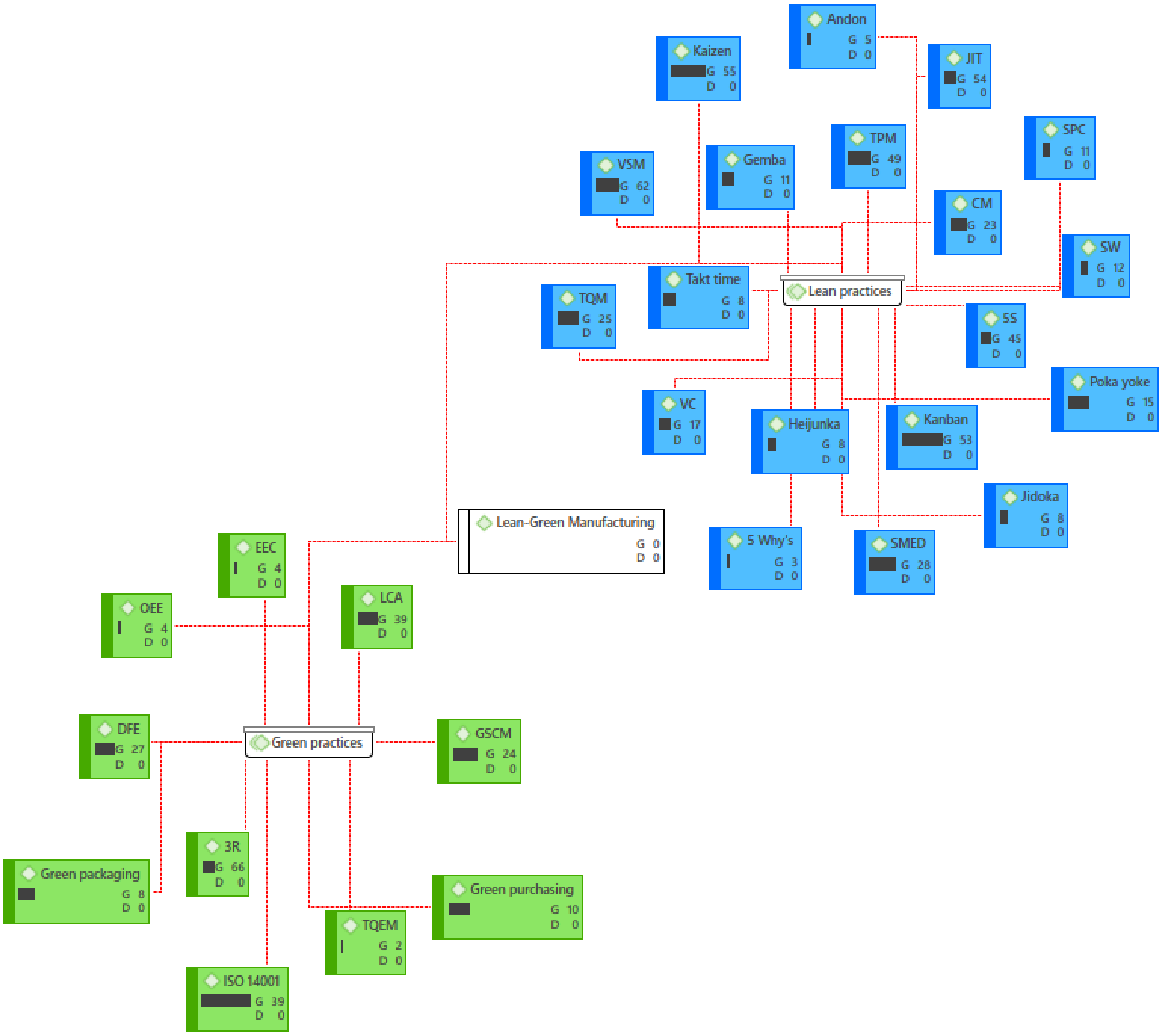

Figure 4.1: Lean and Green practices

Legend: G is the groundedness, which shows how many quotations are linked to a code.
DFE - Design For Environment, 3R – Reduce, Recycle and Reuse, TQEM – Total Quality Environmental Management, OEE – Overall Equipment Effectiveness, LCA – Life Cycle Assessment, EEC – Environmental Emission Control, EMS – Environmental Management System, GSCM – Green Supply Chain Management, VC – Visual Control, JIT – Just in Time, SMED – Single Minute Exchange of Dies, SPC – Statistical Process Control, SW – standardised work, CM – Cellular Manufacturing, TPM – Total Preventive Maintenance, VSM – Value Stream Mapping, TQM – Total Quality Management, 5S – Housekeeping

Figure 4.2 outlines the paper distribution and their countries of origin. India contributed 32 papers, and Brazil contributed 16 papers. Countries such as Slovakia, Slovenia, and South Africa contributed 1 paper each.

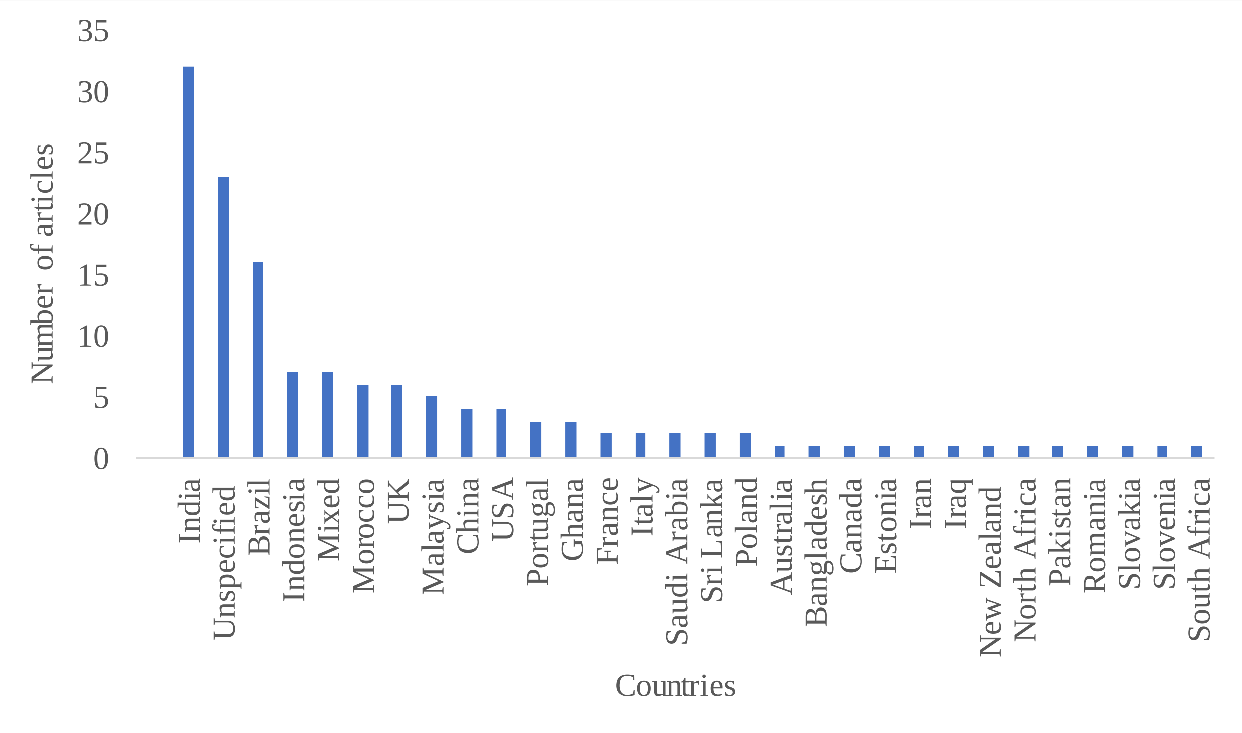

Figure 4.2: Number of papers in each country

According to Figure 4.3, 39% of the papers followed the case study method, while 34% were based on a literature review, and 27% were conducted through surveys.

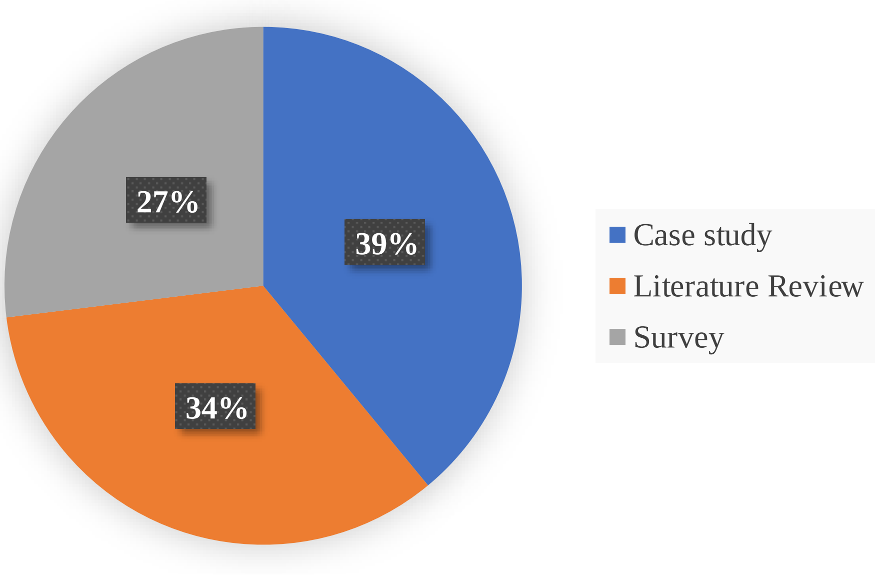

Figure 4.3: Type of research

Figure 4.4 presents the size of the organisation in which the research was conducted. Most papers (62%) did not state the size of the organisation where their study was done. 18% of the papers were conducted in large enterprises, while 15% were conducted in Small and Medium Enterprises (SMEs).

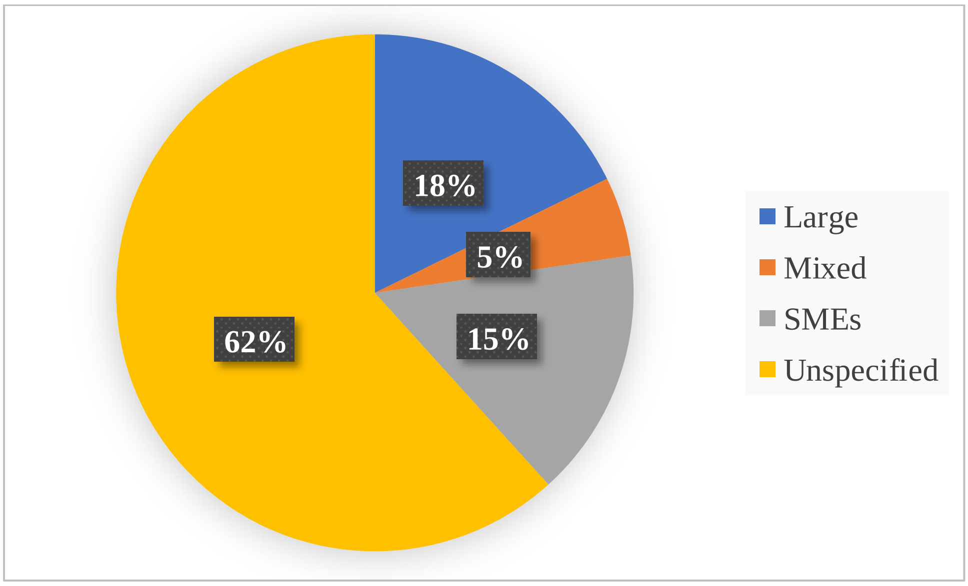

Figure 4.4: Size of the industry

From Figure 4.5, it can be seen that Lean-Green is an emerging area of research as most articles are recent. From 2014 to 2021, the number of articles increased, showing growth in interest on the Lean-Green research.

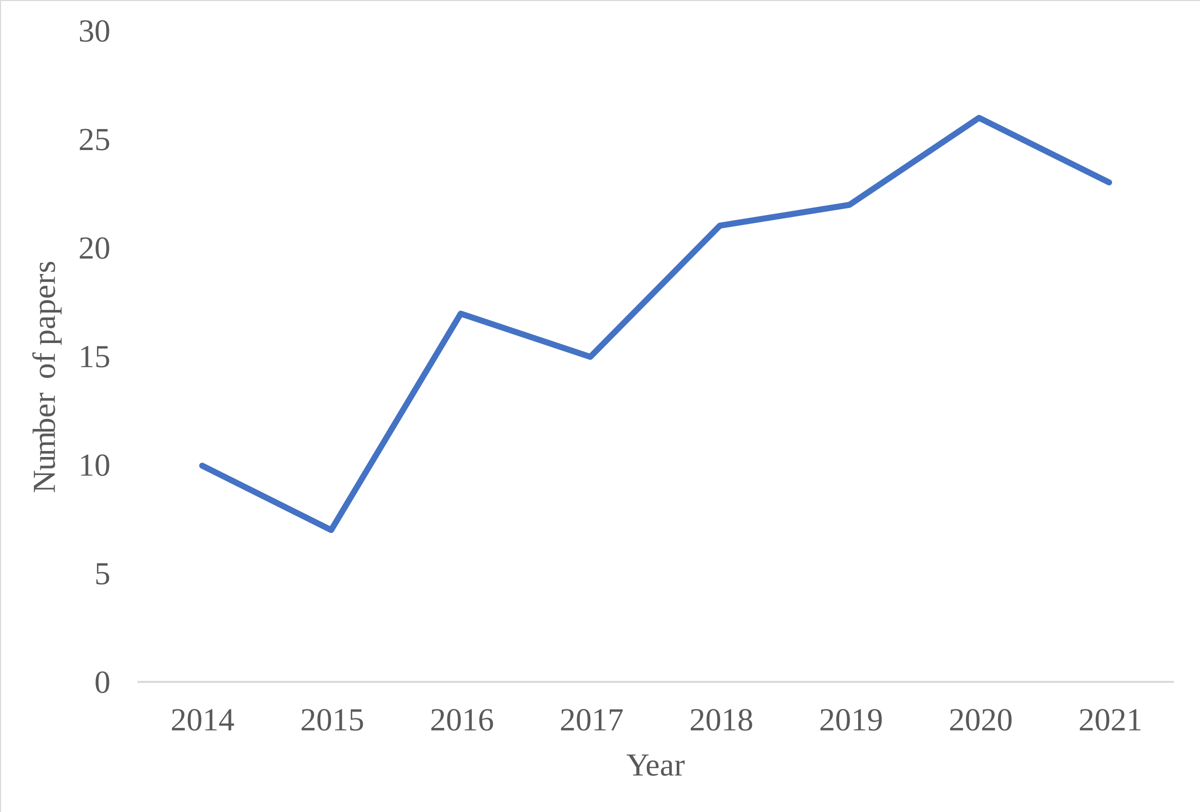

Figure 4.5: Number of papers and year of publication

4.2.3.2 Synergies and divergences between Lean and Green Manufacturing

4.2.3.2.1 General overlap showing the complementary and conflicting issues between LM and GM

The information in Table 2.1 was used to identify the areas for LM and GM that are contradictory and complementary and hence develop the general overlap in Figure 4.6, extending Dües *et al*. (2013) work. This overlap is now bigger than the one proposed by Dües *et al*. (2013) since on top of areas found by Dües *et al*. (2013), the student added some areas that were missing pre-2013 which he discovered from post-2013 articles. Nevertheless, this general overlap shows a lot of agreement with the one proposed by Dües *et al*. (2013). LM and GM both emphasise identifying waste and finding ways to eliminate it (Hallam and Contreras, 2016a; Ghobakhloo *et al*., 2018; Thanki and Thakkar, 2018a), which is the main point of similarity (Lerher *et al*., 2016; Leme *et al*., 2018). Although LM and GM have different definitions of waste, they both consider waste to be non-value-added activities. Although LM and GM define value differently, they both seek to add value (Prasetyawan, 2016), mainly from operations and environmental perspectives respectively (Leong *et al*., 2020); hence they both improve sustainable performance (Pampanelli *et al*., 2016). As a result, integrating LM and GM does not impede the elimination of Lean or Green waste but rather opens the doors for improved waste reduction. LM and GM techniques are motivated by the desire to satisfy the customers. Although the Lean customers are concerned more about the cost of products while the Green customers worry about environmental impacts, LM and GM are both centred on pleasing the customers. Hence, Lean customers will not be concerned about incorporating Green practices as long as the adoption of Green does not cause an increase in the cost of products. On the same note, Green customers will not mind paying less as long as the products are made in an environmentally friendly manner. Thus, when Lean and Green are combined where possible, the customers are more pleased, as some are both environmentally and cost conscious.

In addition to Dües *et al.* (2013), the general overlap from this study indicated that both LM and GM focus on continuous improvement (Wadhwa, 2014; Farias, Santos, Cláudia Fabiana Farias, *et al.*, 2019). Hence, they both focus on long-term thinking as they have long-term effects; for example, environmental impacts affect the environment for a long period (Duarte and Cruz-Machado, 2018). Also, the two methodologies can help organisations enhance their sustainable performance. However, LM affects the profit (economic) and people (social) more, while GM influences the planet (environmental) more (Pampanelli *et al.*, 2016). In addition, the adoption of LM reduces the non-value-adding activities, thus, making organisations increase profits, while GM, on the other hand, makes organisations more competitive (Kaswan *et al.*, 2020) by meeting the demands of those environmentally conscious customers (Huo *et al.*, 2019). In LM, value is created by producing products that attract customers based on their price, whereas in GM, value is created by pleasing customers through manufacturing products in an environmentally friendly manner. Additionally, Dües *et al.* (2013) identified the 7 common Lean wastes; however, most researchers have noted that the Lean waste can be extended to 8 wastes. For instance, Tiwari and Tiwari (2016); Verrier *et al*. (2016); Logesh *et al.* (2017); da Silva *et al.*, (2021) identified loss of creativity as the eighth waste, while Fercoq *et al.* (2016) and Zekhnini *et al.* (2021) identified environmental waste as the eighth waste. In addition, the results from this study showed that the most common Lean practice is VSM, while 3R is the most common Green practice.

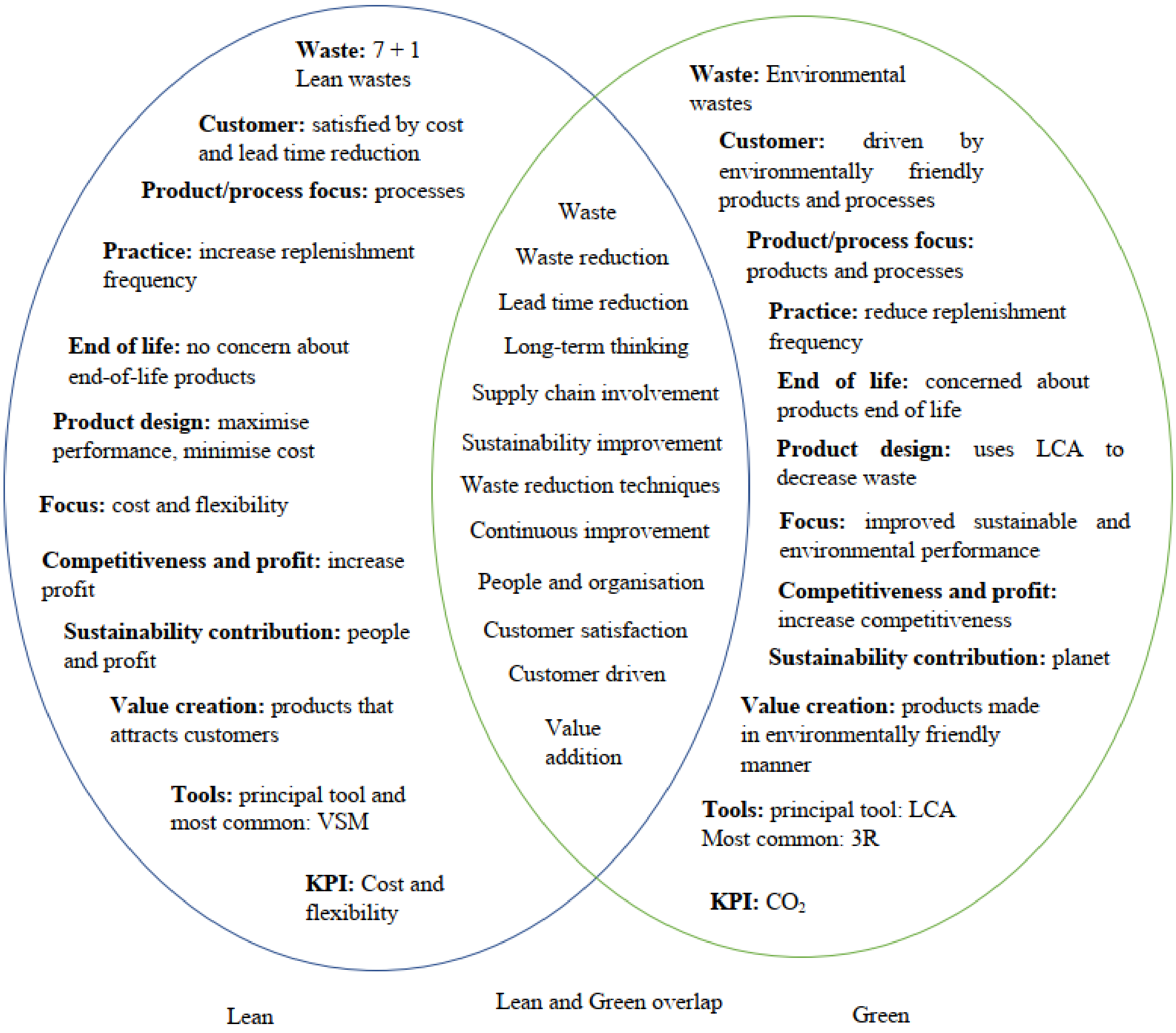

Figure 4.6: General overview showing the complementary and contradicting areas between LM and GM extended post Dües *et al*. (2013)

4.2.3.2.2 Overlap of the relationship between LM and GM towards environmental and operational performance

Environmental and operational performance measures were identified from the literature and constituted the performance criteria (Nallusamy *et al.*, 2015; Kuppusamy *et al.*, 2017; Dawood and Abdullah, 2018; Farias *et al.*, 2019; Thanki and Thakkar, 2019). Since LM is more concerned about improving operational performance while GM is interested in environmental performance (Abreu *et al.*, 2017; Inman and Green, 2018), this motivated the student to investigate the impact of LM and GM practices on operational and environmental performance. The performance measures were linked to Lean and Green practices through a matrix, as shown in Table 4.1. Nine performance criteria were identified, namely: profitability, productivity, inventory reduction, delivery improvement, quality improvement, cost reduction, waste management, environmental impacts, and energy utilisation. These nine performance criteria were divided into sub-criteria. However, the profitability criteria and some sub-criteria like return on sales, return on assets, return on investments, capacity utilisation, equipment reliability and processing time were excluded from the matrix as no author reported on their use towards environmental and operational performance. Furthermore, LM and GM practices such as 5 why's and Andon were excluded from the matrix as no article reported on the application of these practices in improving specific environmental or operational sub-criteria. The selected Green practices are LCA, DFE, 3R, GSCM, Green Purchasing (GP), EEC and ISO 14001, while the Lean practices are TQM, Kaizen, 5S, VSM, JIT, Jidoka, TPM, CM, Kanban and SMED.

Table 4-1: Matrix for the relation between performance criteria and Lean-Green practices

Performance criteria	Sub-criteria	Lean-Green practices																
		Kanban	SMED	CM	VSM	5S	TPM	Kaizen	TQM	JIT	Jidoka	ISO 14001	3R	DFE	LCA	GSCM	EEC	GP
Productivity	Productivity improvement	71	23					5										
	Lead time reduction	71	29 71	55	15 69		15	15 54 55							69			
	Set up time reduction	71	4 32 71		69										69			
	Cycle time reduction	15	15					54										
	Value-added time	71	23		59 69										69			
	Customer satisfaction								46	46					46			
Inventory reduction	Inventory reduction	23 71	23		69													
Delivery improve	Delivery performance	15	15		15	15	15	15										
Quality improvement	Product quality					15 48	15 48	15	46	46					46			
Cost reduction	Cost reduction		71	55	15	15	15	5 15 55 11	46	46		45	9		46	9		

Waste managem	Waste reduction		71	55		71	15 4 54	53 55 11			54		10					
	Material usage	71	21 23 71	23	21 23 54	21 23	4 21 23 54	5 38 54 11	23		54	53	53					
	Waste water reduction							11				15	15 70	15		9		
	Solid waste reduction											15	15 70	15				
Environmental impacts	Environmental performance				69			5	25				48	24 48	49 69 48		48	48
	Emission reduction		32			4 59	4 71					15	15 70	15				
Energy utilisation	Energy consumption	23 71	4 23 71	23 4	23	23	23 71 54		23 46	46	54	9 15	9 15 22	15	15	46		

Note: the numbers in Table 4.1 correspond to the following authors.

4 - Chiarini (2014) 5 - Pampanelli *et al.* (2014) 9 - Wiese *et al.* (2015)
10 - Fercoq *et al*. (2016) 11 -Pampanelli *et al*.(2016) 15- Thanki *et al.* (2016)
21 – Cherrafi *et al.* (2017c) 22 -Whyle and Bland (2017) 23 - Belhadi *et al.* (2018)
24 - Dawood and Abdullah (2018) 25 - Green *et al.*, (2018)
29 - Ikatrinasari *et al.* (2018) 32 - Leme *et al.* (2018) 38 - Cherrafi *et al.* (2019)
45 - Dieste and Panizzolo (2019) 46 - Agyabeng-mensah *et al. (*2020)
48 - Ahmad *et al*. (2020) 49 - Belhadi *et al.* (2020) 53 - Logesh and Balaji (2020)
54 - Silva *et al.* (2020) 55 - Udokporo *et al*. (2020b)
57. Vinayagasundaram *et al*. (2020) 59 - Zhu *et al.* (2020) 69 - Salvador *et al.* (2021)
70 - Suhardini and Hadiwidjojo (2021)

For further clarification, Figure 4.7 shows how the selected Lean and Green practices influence the 8 groups of performance criteria. Lean-Green has a greater impact on waste management, environmental impacts, productivity, and energy utilisation compared to inventory reduction and delivery improvement. Kaizen and 3R were the most common practices on environmental and operational performance, while EEC and Green purchasing were the least used practices.

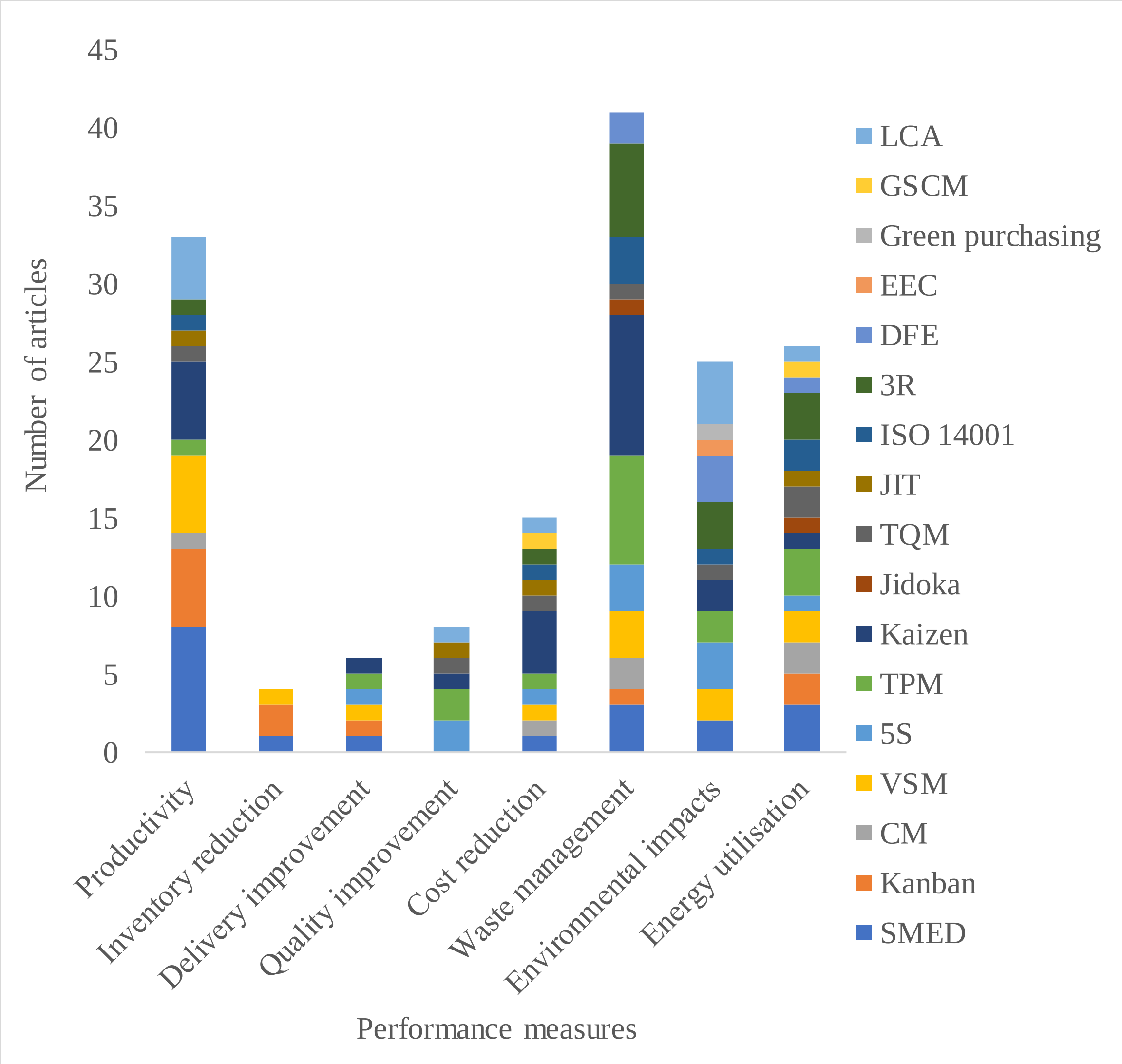

Figure 4.7: Relationships between performance criteria and Lean-Green practices.

In a bid to further examine the complementary and conflicting areas of LM and GM, another Lean-Green overlap was developed based on environmental and operational performance. This is another important area to consider; however, it was not combined into the overlap in Figure 4.6 because the diagram would be too big. Therefore, the overlap on environmental and operational performance in Figure 4.7, as well as LM and GM techniques in Figure 4.8, were highlighted separately. As shown in Figure 4.7, both LM and GM impact operational and environmental performance (Hallam and Contreras, 2016a). However, LM practices are much more focused on improving operational performance. Operational performance sub-criteria such as productivity improvement, inventory reduction, delivery improvement and cycle time reduction are affected by Lean practices only. A framework developed by Farias *et al.* (2019) also indicated that GM practices do not affect inventory reduction and productivity.

The overlap agrees with the study by Dües *et al.* (2013) that indicated the synergies in lead time reduction and waste reduction. In addition, the overlap also shows that LM and GM complement each other in setup time reduction, value-added time, customer satisfaction, quality improvement, cost reduction, material usage, environmental performance, and energy consumption. Thus, the implementation of GM supports LM by reducing costs through a decrease in energy consumption, material usage, and waste. This agrees with Fercoq *et al*. (2016) and Reis *et al*. (2017), who noted that integrating LM and GM reduces costs. Therefore, the simultaneous implementation of LM and GM has a greater impact on organisational performance than their individual implementation. Although LM and GM show divergences in productivity improvement, inventory reduction, delivery improvement, and cycle time reduction sub-criteria, they are still compatible.

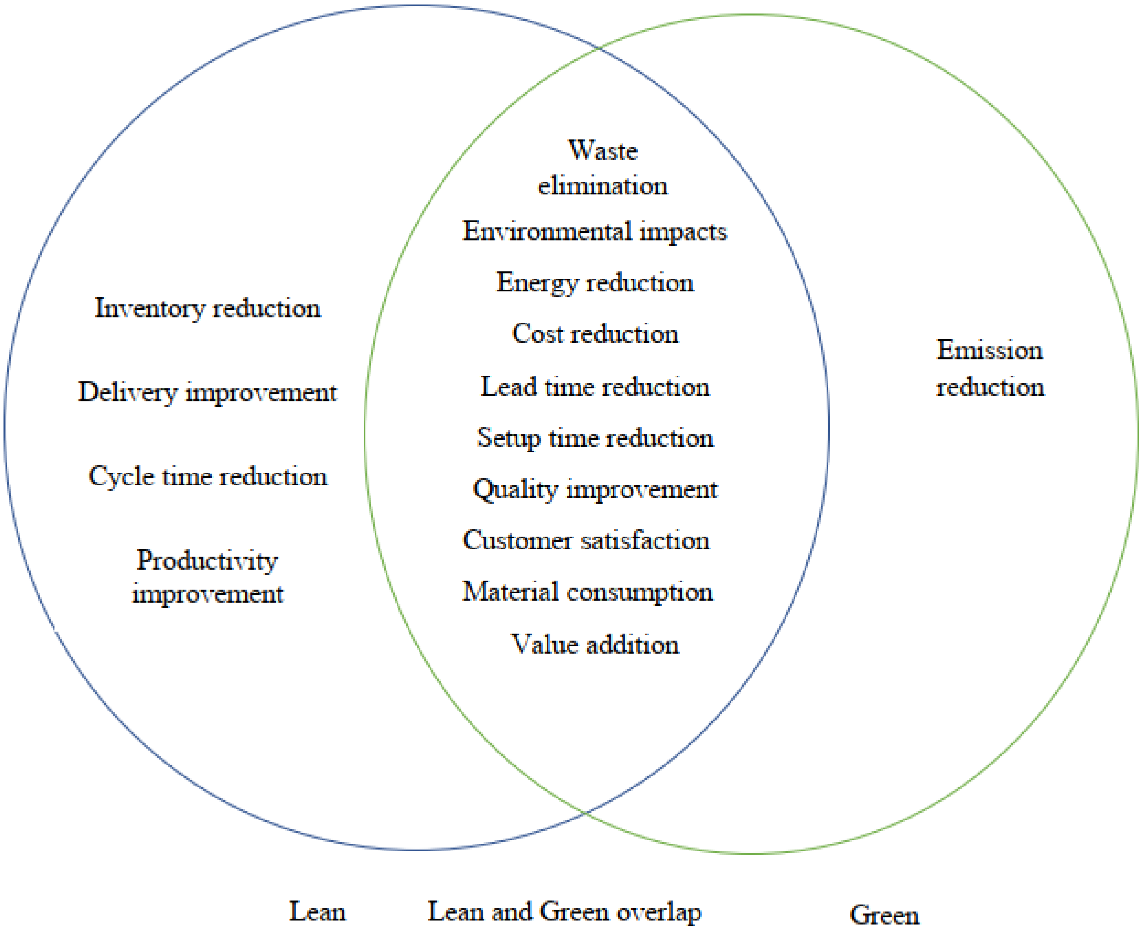

Figure 4.8: Overlap between LM and GM for operational and environmental performance

4.2.3.2.3 Overlap showing the complementary and contradicting techniques between Lean and Green

Figure 4.9 shows an overlap between the Lean and Green practices deployed for improved operational and environmental performance. The Lean-Green matrix in Table 4.1 was used to determine if the LM and GM practices are complementary or contradicting. This extends the work by Dües *et al*. (2013) that did not include these practices except that the study identified the principal practices. The results obtained show that most practices are complementary. This agrees with Salvador *et al*. (2021) who noted that LCA and VSM show common attributes. It was noted that VSM could be extended to Green VSM by incorporating the Green aspect into traditional VSM (Hartini *et al*., 2021).

Emission reduction seemed to be contradictory to Lean-Green integration. This agrees with Campos and Vazquez-brust (2016), Dawood and Abdullah (2017), Baumer-Cardoso *et al.* (2020); Jbira *et al.* (2020), who noted that JIT delivery and inventory reduction showed divergencies with GM due to increasing emissions. JIT entails delivering raw materials when needed; hence, organisations will keep less inventory. However, as much as this supports LM, increased transportation increases carbon dioxide emissions (Campos and Vazquez-brust, 2016).

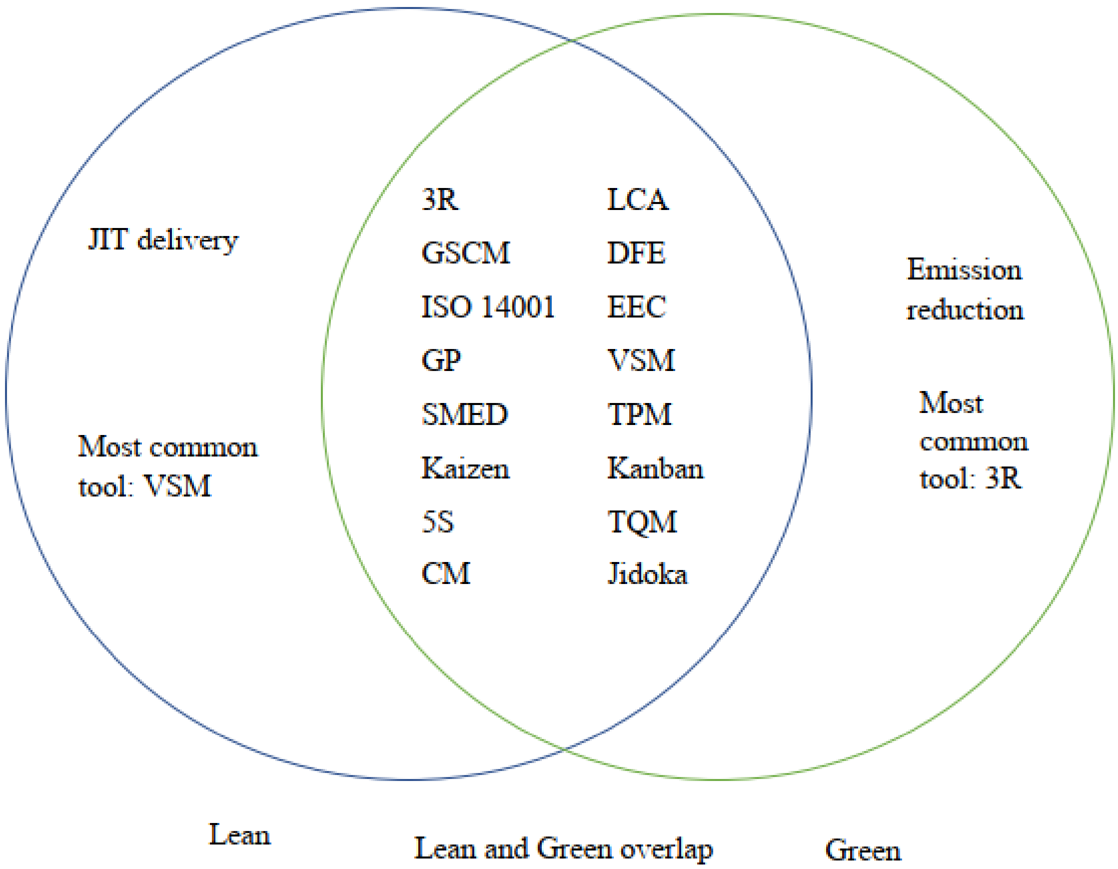

Figure 4.9: Overlap showing the complementary and contradicting techniques between Lean and Green

4.2.3.3 Identified study themes

The research themes were identified through lower-order and higher-order coding using ATLAS.ti version 22. Figure 4.10 shows the 6 thematic areas which were further explained in Table 4.2, excluding performance improvement, synergy, and divergence themes that have already been explained.

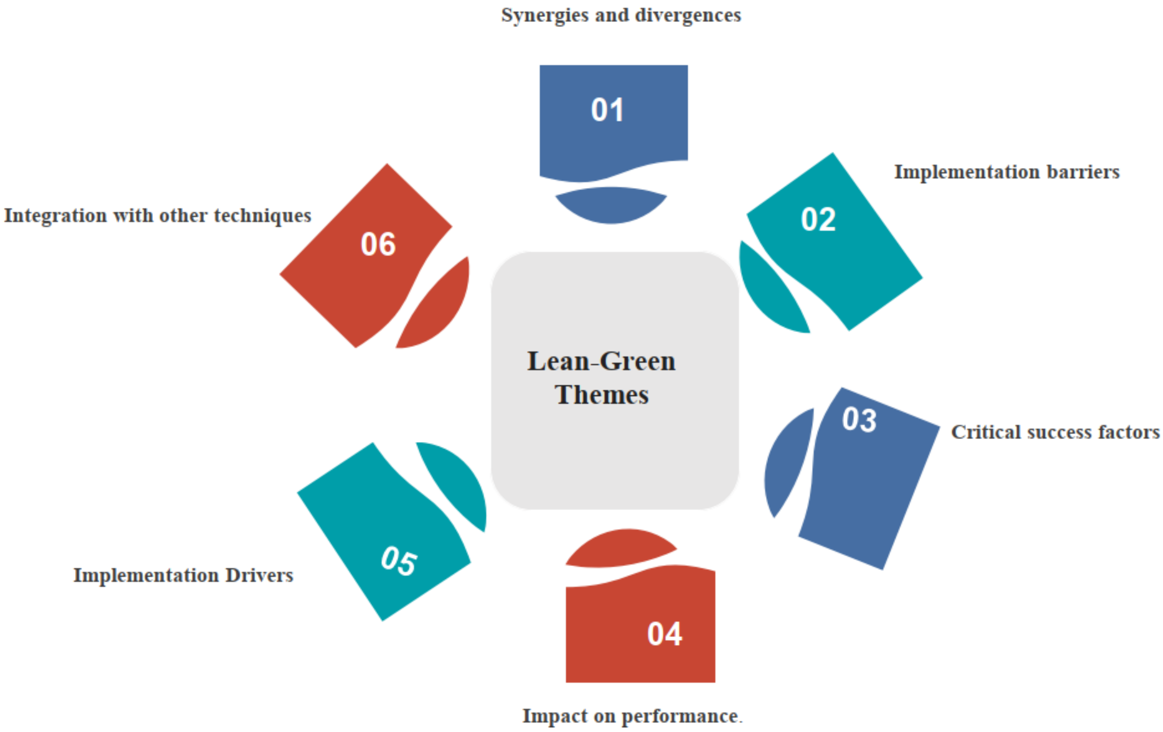

Figure 4.10: Other Lean-Green themes

Table 4-2: Study themes

Theme	Supporting references
Integration with other techniques	LM and GM can be integrated with other manufacturing techniques to improve the performance of the companies. The review indicated that Lean-Green Manufacturing could be integrated with Six Sigma to enhance organisational performance (Banawi and Bilec, 2014; Garza-reyes *et al.*, 2014; Garza-Reyes, 2015; Rahman and Ogunleye, 2019; Gaikwad and Sunnapwar, 2020; Kaswan, *et al.*, 2020; Sony and Naik, 2020; Strategy *et al.*, 2021). Sustainability can be improved by combining the industry 4.0 elements into Lean-Green practices (Duarte and Cruz-Machado, 2018; Edirisuriya *et al.*, 2019; Leong *et al.*, 2020; Kaswan and Rathi, 2020b; Tripathi *et al.*, 2021; Zekhnini *et al.*, 2021), for example, logistic 4.0 (Edirisuriya *et al.*, 2019). Big data analytics can be integrated into Lean-Green practices to improve environmental performance (Belhadi *et al.*, 2020). Other advanced technologies that support the integration of LM and GM supply chain are Internet of Things (IoT), Radio Frequency Identification (RFID) and cloud computing (Carvalho, Pimentel, *et al.*, 2019). Agile Manufacturing can be combined with Lean-Green, to attain sustainability (Garza-Reyes, 2015; Singh *et al.*, 2019; Udokporoa *et al.*, 2020a; Udokporo *et al.*, 2020b). In addition, Resilient can be combined with Lean-Green for improved organisational performance (Garza-Reyes, 2015;

	Ruiz-Benitez *et al.*, 2017). Lean-Green can be integrated with Agile and Resilient practices to improve supply chain performances (Rachid and Ayyad, 2017; Piprani *et al.*, 2021; Sharma *et al.*, 2021). The Lean-Green supply chains can also be enhanced by adopting additive manufacturing (Torres *et al.*, 2020).
Implementation barriers	The implementation barriers address factors that prevent the successful implementation of Lean-Green, such as lack of top management commitment (Mittal *et al.*, 2016; Singh *et al.*, 2019; Cherrafi *et al.*, 2021), fear of change, lack of employee training (Siegel *et al.*, 2019; Kaswan *et al.*, 2020; Harisekar, 2021), negative culture (Pampanelli *et al.*, 2016; Cherrafi *et al.*, 2017b; Kaswan *et al.*, 2020; Singh *et al.*, 2020). Harikannan *et al.* (2018) depicted a lack of research and development, poor organisational structure, and lack of design and testing barriers. Other discussed barriers are lack of government assistance (Bharadwaj and Sundar 2016; Cherrafi *et al.*, 2017b; Leong *et al.*, 2019b; Sindhwani *et al.*, 2019), lack of finance (Oliveira, Tan and Guedes, 2018 Rahman and Ogunleye 2019; Kaswan *et al.*, 2020), lack of expertise (Pampanelli *et al.*, 2016; Cherrafi *et al.*, 2017b), and lack of knowledge (Kaswan *et al.*, 2020). The other identified barriers include an unstable political environment, lack of customer involvement, lack of government supporting policy, technical incompetency, poor quality of manufacturing facilities, resistance to technology adoption, and supplier reluctance to change (Kumar *et al.*, 2015). In addition, some of the barriers are lack of Lean-Green thinking (Cherrafi *et al.*, 2017b), lack of Kaizen environment, poor project implementation, ineffective implementation method, ineffective time and resource mismanagement (Zhu and Zhang, 2020), lack of proper data collection and performance measures (Singh *et al.*, 2019) and lack of awareness (David and Found, 2016; Cherrafi, Elfezazi, Garza-Reyes, *et al.*, 2017b; Siegel *et al.*, 2019), fear of failure, fund constraints, lack of visual and statistical control, high cost (Chiet *et al.*, 2019) and lack of communication (Cherrafi *et al.*, 2017b; Szymańska-brałkowska and Malinowska, 2018).
Critical success factors (CSFs)	CSFs are factors that make the integration of LM and GM successful; hence, their identification and communication help organisations focus on important issues and avoid wasting resources on less vital things (Mishra, 2018). They include management vision, commitment, involvement (Pampanelli *et al.*, 2016; Kaswan and Rathi, 2020b; Baskiewicz and Barbu, 2021), training and education (Pampanelli *et al.*, 2014; Siegel *et al.*, 2019; Gaikwad and Sunnapwar, 2020), successful communication, technology innovation, customer satisfaction (Kaswan and Rathi,

	2020b). In addition, some CSFs are culture change (Pampanelli *et al.*, 2014; Pampanelli *et al.*, 2016; Gaikwad and Sunnapwar, 2020), governmental support, motivation of employees and rewards, financial capabilities (Thanki and Thakkar, 2018b; Baskiewicz and Barbu, 2021), project management skills, quality management practices, and successful use of statistical practices (Rahman and Ogunleye, 2019). Mishra (2018) highlighted the readiness of the organisation, resources selection, and priority of the project as other CSFs.
Implementation Drivers	The drivers are those factors that push companies to integrate LM and GM. They include cost reduction and profitability, the satisfaction of employees, shareholders' complaints, improvement of processes, corporate image improvement, regulations, consumer requirements, government policies (Cherrafi *et al.*, 2017a), competitiveness (Jaiswal and Kumar, 2018), public pressure, and cost reduction (Gandhi *et al*., 2018).

The qualitative method has enabled the student to determine the synergies and divergencies between LM and GM. In addition, research themes were determined using ATLAS.ti coding. The following sections are now based on the quantitative method using SEM.

4.3 Results from the quantitative method

This section starts by highlighting the profile of the respondents followed by outlining the different models that were constructed using SEM in SMART PLS.

4.3.1 Profile of the participants

Tables 4.3 to 4.6 show the profile of the respondents that participated in the survey. The distribution of the companies is indicated in Table 4.3. The highest responses per sector were 89 from the food and beverage sector, followed by 33 from plastic and rubber.

Table 4-3: Type of industry

Type of industry	Number of respondents	%
Food and beverage	89	29.5
Chemicals and petrochemicals	24	7.9
Plastic and rubber	33	10.9
Pharmaceutical	6	2.0
Agrochemical	17	5.6
Wood and furniture	19	6.3
Electronics and electrical	27	8.9
Fertilizer	7	2.3
Textiles	15	5.0
Leather	6	2.0
Paper	10	3.3
Ceramic	5	1.7
Steel	13	4.3
Tiles and bricks	11	3.6
Automotive	5	1.7
Battery	7	2.3
Foundry	8	2.6

According to Table 4.4, 39 respondents indicated that their companies have less than 41 employees, while 37 respondents highlighted that their companies had 41-75 employees. According to Matipira and Magaisa (2019) companies with less than 41 employees are classified as small enterprises, while those with employees ranging from 41– 75 are classified as medium sized enterprises. Thus, the total number of SMEs who participated in this study is 76. Therefore, 226 companies are classified as large enterprises. This suggests that large companies are implementing improvement methodologies such as Lean-Green more, compared to SMEs. This may be due to the fact that large enterprises have more resources that are required for a successful implementation process.

Table 4-4: Number of employees

Number of employees	Frequency	%
under 41	39	12.9
41-75	37	12.3
76-150	56	18.5
151-250	41	13.6
251-350	56	18.5
over 350	73	24.2

Table 4.5 shows that most respondents (58.9%) were middle managers, such as operations managers, Safety, Health, and Environment (SHE) managers, and quality managers. Top management, such as the Chief Executive Officer (CEOs) and managing directors, contributed 34.1%; while lower managers, such as production and quality supervisors, contributed 7%.

Table 4-5: Position of the respondents

Position of the respondent	Frequency	%
Top manager	103	34.1
Middle manager	178	58.9
Lower manager	21	7.0

The majority of the participants indicated that they have more than 5 years of experience in their current positions. This experience is good enough to respond to the items on the questionnaire (Huo *et al.*, 2019). Table 4.6 shows the respondents' years of experience in their current positions.

Table 4-6: Years in position

Years in position	Frequency	%
5 and below	22	7.3
6 - 10	55	18.2
11 -15	205	67.9
16-20	10	3.3
21 - 25	5	1.7
above 25	2	0.7
Missing	3	1.0

4.3.2 Evaluation of the impact of Lean-Green practices on environmental and operational performance

4.3.2.1 Introduction

This section explores how LM and GM complement one another in terms of operational and environmental performance. It investigates if implementing LM and GM together improves organisational performance over implementing them separately. It also assesses whether being environmentally conscious improves business performance. A survey of Zimbabwe's manufacturing industry was done. 302 valid responses were gathered from the 782 questionnaires issued. The data was analysed using PLS-SEM. The results showed that both LM and GM have an impact on environmental and operational performance. However, GM indirectly affects operational performance through environmental performance. Furthermore, the impact of combining LM and GM was larger than when they were used alone. As a result, organisations that have successfully implemented LM will find it easier to deploy GM due to their complementary nature. Most types of waste are reduced when LM and GM are combined, resulting in enhanced environmental performance, improved community relations, and increased customer satisfaction.

4.3.2.2 Brief background

Various authors have reported on the impact of either LM or GM on organisational performance (Kumar, 2017; Rehman *et al.*, 2016; Negrão *et al.*, 2017; Singh, 2021). However, this research investigates the impact of combined Lean-Green on operational and environmental performances. In addition, it investigates whether the joint impact of Lean-Green is greater than when LM and GM are implemented separately.

4.3.2.3 Hypotheses formulation and development of the research model

A second-order structural model was developed to examine the impact of LM and GM on organisational performance. This model, as shown in Figure 4.11, consisted of one endogenous variable: the operational performance, and three exogenous variables, namely, GM, LM and environmental performance. LM and GM are the second order latent variables where 3R, LCA and Green purchasing are first-order latent variables for GM, while JIT, TQM, TPM and employee involvement are the first-order latent variables for LM. In research to examine the impact LM on organisational performance, Hernandez-Matias *et al.* (2019) applied employee involvement and realised improvements. Accordingly, Arumugam *et al.* (2020) adopted JIT, TQM and TPM and concluded that LM positively impacts organisational performance. Additionally, Khan *et al.* (2019) applied green purchasing and Dawood and Abdullah (2017) used 3R and realised an improvement in organisational performance. Moreover, Dües *et al.* (2013) mentioned that LCA is the principal GM tool. As a result, this motivated the student to adopt these LM and GM practices, but this time, examining the complementary impact of LM and GM implementation.

LM and GM have a synergy since they both aim to eliminate wastes (Farias *et al.*, 2019). Elimination of Lean wastes like defects, over-processing, and overproduction supports the GM philosophy due to the efficient use of resources such as water, energy, and raw materials. It was further highlighted that LM outlines a way for the utilisation of resources and reduction in waste associated with the manufacturing processes (Pampanelli *et al*., 2014). Lean practices are therefore treated as Green because their objectives align with saving resources (Fercoq *et al*., 2016). Balaji and Logesh (2020) concluded that GM is attained by reducing Lean wastes during manufacturing. Kuo and Lin's (2020) study demonstrated that LM positively influences green operations. LM supports Green by eliminating wastes, including Green wastes (Baumer-Cardoso *et al.*, 2020). It can, therefore, be hypothesised that:

H1: LM is positively related to GM.

LM has been traditionally employed to minimise the seven wastes; however, Fercoq *et al.* (2016) acknowledged that Lean practices might also reduce the environmental waste. Several articles have indicated that LM has a positive impact on environmental performance (Dong *et al.*, 2019). For example, Kamble *et al.* (2020) concluded that LM had a significant effect on environmental performance. The research of Jabbour *et al.* (2013) in the automotive industry concluded that a strong relationship exists between LM and environmental performance. The Lean practices employed were TPM and JIT. The objective of JIT is to ensure that the right quantity of resources is provided at the right time, thus preventing unnecessary inventory (Arumugam *et al*., 2020). Balaji and Logesh (2020) added that the goal of LM is to eliminate defects and manage inventory (Logesh and Balaji, 2020). TPM aims to increase equipment efficiency and reduce waste through maintenance such as lubrication, cleaning, and calibration (Jabbour *et al.*, 2013). Thus, those organisations that adopt LM achieve high levels of pollution prevention due to inventory reduction, amongst other things. Therefore, it is hypothesised that:

H2: LM is positively associated with environmental performance.

Manufacturing companies are implementing Lean practices such as TQM, JIT and TPM to improve quality and productivity by eliminating waste. In Zimbabwe, Maware and Adetunji's (2019a) study on manufacturing companies highlighted that LM positively impacts operational performance. The authors added that the integration of people in LM allows for the involvement, motivation, and training of workers, hence, creating room for improvement. Pampanelli *et al.* (2014) outlined that the main goal of LM is to improve delivery, quality, and reduce cost. Farias *et al.* (2019) emphasised that implementing LM made the organisations improve their operational performance. In addition, the authors stated that successful LM implementation leads to improved utilisation of resources. Baumer-cardoso *et al.* (2020) applied LM in a Brazilian job shop and realised a reduction in setup time and energy consumption leading to a significant decrease in costs. Hence, it can be hypothesised that:

H3: LM has a positive influence on operational performance**.**

The GM philosophy has been well recognised for reducing negative ecological issues (Garza-Reyes, 2015). It aims to reduce waste, improve, control and monitor pollution levels, minimise the impact of manufacturing processes on the environment, and provide for efficient use of resources (Farias *et al.*, 2019). Its purpose is also to reduce the negative impacts of production on the environment (Ramos *et al.*, 2018). It examines environmental wastes related to unnecessary use of energy or water, eutrophication and the greenhouse effect (Baumer-Cardoso *et al.*, 2020). GM advocates for the elimination of solid wastes, hazardous wastes, air emissions, wastewater discharge, and other forms of pollution (Abualfaraa *et al.*, 2020). It supports the use of processes and manufacturing products that do not harm the environment (Mudgal *et al.*, 2009). Chiou *et al.* (2011) stated that greening the processes positively impacts environmental performance. GM was found to have a strong relationship with environmental performance (Belhadi *et al.*, 2019). It can, therefore, be postulated that:

H4: GM is positively related to environmental performance.

GM's objective is to reduce waste and pollution levels and provide efficient resource usage (Qureshi *et al*., 2015). If water, energy, raw materials and other resources can be used efficiently, the cost can be reduced, leading to improved operational performance. The research in the Chinese fashion industry concluded that GM implementation positively affects the performance of organisations (Li *et al*., 2019). The study by Rehman *et al.* (2013) in the Indian steel industry concluded that implementing GM improves operational performance. Furthermore, green practices were found to impact Pakistani manufacturing organisational performance (Khan *et al*., 2019). Thus, it can be hypothesised that:

H5: GM has a positive relation to operational performance.

The study by Jabbour *et al.* (2013) in the Brazilian industry outlined that environmental performance positively influences operational performance. The operational performance measures used are cost, quality, flexibility, and delivery. It was further explained that adopting environmental management techniques improves operational performance. The study done on Chinese manufacturing companies concluded that implementing environmental policies positively impacts company performance (Zhang and Du, 2020). It was also noted that environmental collaboration plays a significant part on organisational perfomance (Ai *et al.*, 2015). According to research on Thailand's food industry, environmental performance improves operational performance in this industry (Pipatprapa *et al.* 2016). Thus, it can be hypothesised that:

H6: Environmental performance is positively related to operational performance.

Over the past years, LM and GM have been implemented separately to improve organisational performance. Nevertheless, researchers have noted that when LM and GM are combined, they yield better results than when implemented alone (Fercoq *et al.*, 2016; Cherrafi *et al.*, 2018; Ramos *et al.*, 2018; Baumer-Cardoso *et al.*, 2020). Green *et al.* (2018) combined JIT, TQM, and GSCM and figured out that when practices are combined, they have a larger impact than when implemented individually. Hence, it can be postulated that:

H7: Integrated LM and GM have a greater impact on environmental performance than individually.

H8: Integrated LM and GM have a greater impact on operational performance than individually.

All these hypotheses taken together allowed for the development of a structural model for evaluating the integrated impact of Lean-Green manufacturing on environmental and operational performance. The model is illustrated in Figure 4.11.

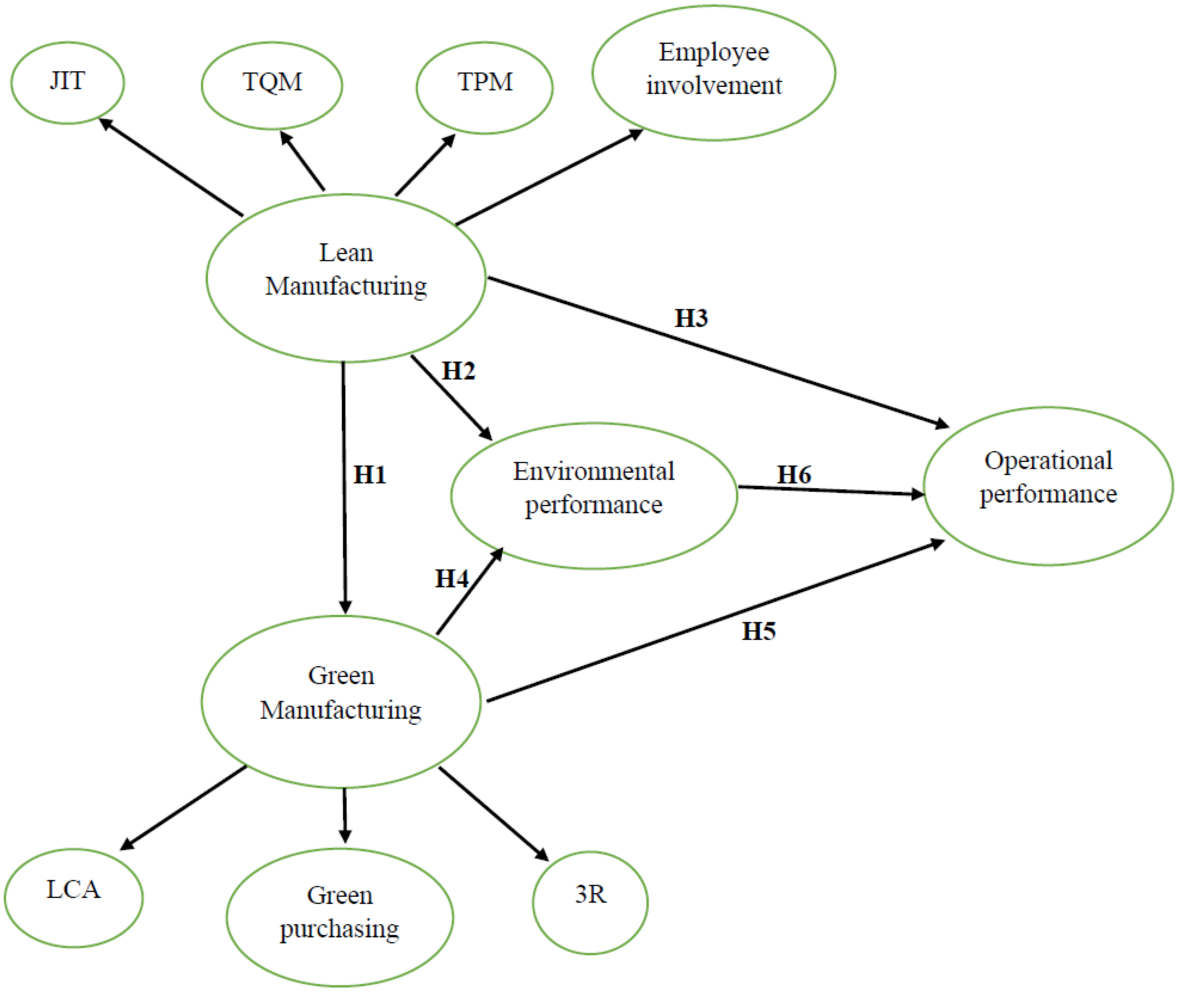

Figure 4.11: Lean-Green structural model

4.3.2.4 Assessment of the measurement scale

Bartlett's test of sphericity had a p-value less than 0.001 showing that it is significant. The sample size of 302 was adequate, as indicated by the Kaiser–Meyer–Olkin (KMO) value of 0.903. Jabbour *et al*. 2013 noted that a KMO value closer to 1 indicates adequate sample. The total variance explained obtained for the latent variables was 63.4%. The measurement scale's reliability was assessed using Cronbach's alpha and composite reliability (Green *et al.*, 2018). The Cronbach's alpha values were all > 0.7, hence they are acceptable (Nunnally, 1978; Zhu and Sarkis, 2004; Firmansyah and Maemunah, 2021). The composite reliability values should be > 0.7, reflecting high internal consistency. The composite reliability values were all > 0.7. The Average Variance Extracted (AVE) is used to assess the convergent validity where values > 0.5 indicates a strong convergent validity (Hair *et al.*, 2017). The AVE values obtained in this research ranged from 0.6-0.8. Firmansyah and Maemunah (2021) noted that outer loadings could be used to assess convergent validity, where variables with values > 0.5 are considered valid. As seen from the model in Figure 4.12, all the outer loadings were > 0.5. All the constructs exhibited discriminant validity as the Heterotrait-Monotrait (HTMT) ratio values did not include 1. Therefore, the scale denotes enough reliability and validity; thus, the variables can be used for further research on hypotheses evaluation.

Table 4-7: Measurement reliability and validity

	Cronbach's Alpha	Composite Reliability	AVE	HTMT values
3R	0.847	0.897	0.686	Does not include 1
Employee Involvement	0.751	0.834	0.502	Does not include 1
Environmental performance	0.886	0.913	0.636	Does not include 1
GM	0.926	0.936	0.501	Does not include 1
Green Purchasing	0.903	0.922	0.598	Does not include 1
JIT	0.83	0.876	0.543	Does not include 1
LM	0.928	0.935	0.509	Does not include 1
LCA	0.848	0.892	0.623	Does not include 1
Operational performance	0.856	0.893	0.582	Does not include 1
TPM	0.837	0.875	0.568	Does not include 1
TQM	0.86	0.891	0.507	Does not include 1

4.3.2.5 Structural model assessment

The VIF values indicate that there was no collinearity problem as they were all below 5 and above 0.2 (Hair *et al.*, 2017). The coefficient of determination (R^2) indicates the predictive power of the model. According to Hair *et al.* (2017), the R^2 values depend on how complex the model is; therefore, R^2 value of 0.20 can be considered high. Cohen (1988); Famiyeh *et al.* (2018) also mentioned that R^2 values greater than 0.26 are substantial, 0.13 are moderate, and 0.02 are weak. The R^2 values of 35.6%, 36.5%, and 51.0% were obtained for GM, environmental performance, and operational performance, respectively. The R^2 for TQM was 73.5%, JIT was 73.1%, TPM was 74.2%, employee involvement was 57.2%, LCA was 79.7%, 3R was 48.5 and green purchasing was 86.1%. The results show that the model had high predictive power and that LM and GM constructs are good environmental and operational performance predictors.

The effect size, f^2, is used to determine the impact of an omitted exogenous variable on the endogenous variable. The f^2 values of 0.35, 0.15, and 0.02 demonstrate large, medium, and small effects, respectively (Hair *et al.*, 2017). Table 4.8 highlights that most of the relationships have a large effect. The relationship between GM and operational performance was denoted by a small effect while LM to environmental performance relationship has a medium effect. The Stone-Geisser's Q^2 value indicates the predictive relevance of the model (Maware and Adetunji, 2019b; Firmansyah and Maemunah, 2021). Q^2 values greater than 0 shows the path model's predictive relevance (Hair *et al.*, 2017). All the Q^2 values obtained were larger than 0, showing good predictive power.

Table 4-8: The f^2 values

	3R	EI	EVP	GM	GP	JIT	LCA	OP	TPM	TQM
EVP								0.396		
GM	0.943		0.352		6.207		3.918	0.024		
LM		1.336	0.152	0.553		2.718		0.354	2.883	2.767

EI – Employee Involvement, EVP – Environmental Performance, GP – Green Purchasing, OP – Operational Performance

Table 4-9: The Stone-Geisser's Q^2 values

Endogenous variable	TPM	JIT	TQM	EI	LCA	3R	GP	GM	EVP	OP
Q^2	0.340	0.390	0.364	0.282	0.490	0.320	0.509	0.161	0.224	0.288

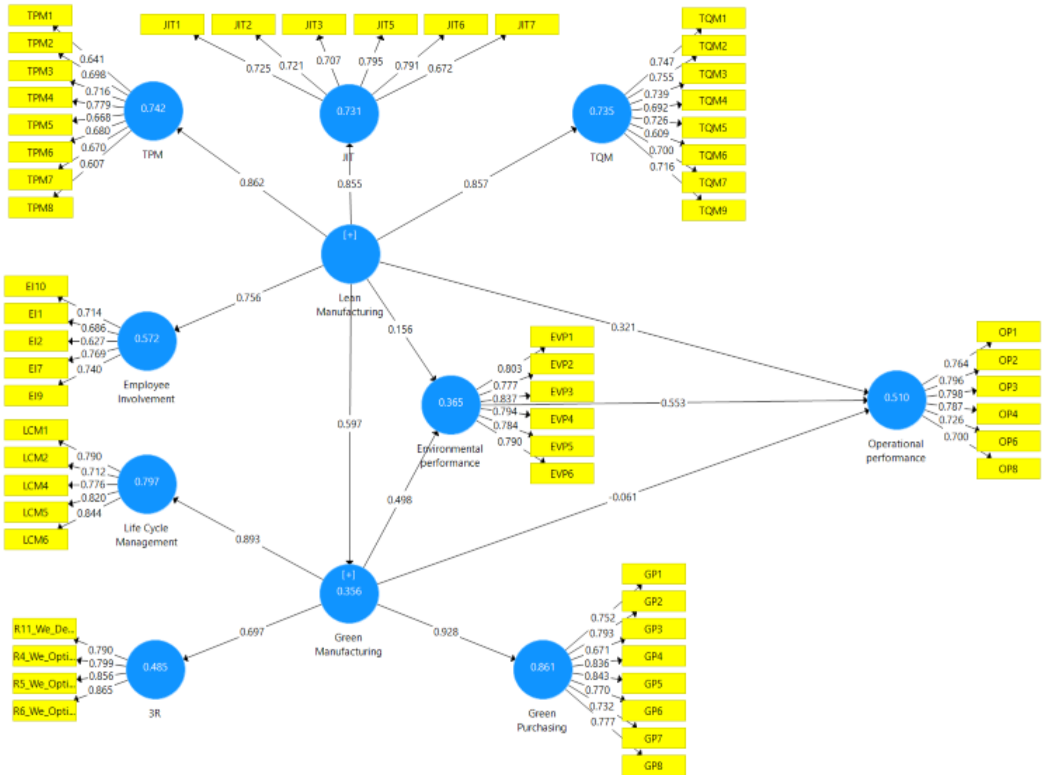

Figure 4.12: Results for the structural model

The significance of the paths was determined through the bootstrapping method using 5000 subsamples (Godinho Filho *et al.*, 2016; Ghobakhloo *et al.*, 2018). Most of the proposed relationships are statistically valid as they had *t* values above 1.96 and *p* values lower than 0.05 at 5% significant level (Hair *et al.*, 2017). Thus, the *t* and *p* values failed to reject the hypotheses except for hypothesis H5. The H5 failed to satisfy the *t* and *p* values; hence it was rejected.

Table 4-10: *t* statistics and *p* values and decision on the hypotheses

	t statistics	*p* values	Decision
Environmental performance → Operational performance	8.924	0.000	supported
GM → Environmental performance	6.777	0.000	supported
GM → Operational performance	0.973	0.331	Not supported*
LM → Environmental performance	2.042	0.042	supported
LM → GM	11.955	0.000	supported
LM → Operational performance	5.377	0.000	supported

*The direct relation between GM and operational performance is not supported, the impact is indirect through environmental performance

To determine if the combined effect is stronger than singular impacts, the student adopted the stepwise regression method, with LM first and GM second, and noting the increments in R^2 (Green *et al*., 2018). Since GM is a new methodology compared to LM, we assumed that organisations that are likely to implement GM, have already adopted LM. In addition, since LM aims at reducing the seven wastes thereby having a positive impact on operational performance, while GM focuses on reducing environmental waste, organisations are likely to adopt LM before GM as most organisations are likely more interested in improving their operational performance ahead of environmental compliance. Accordingly, LM and GM practices were stepwise regressed against environmental and operational performance. When LM was used as the first antecedent to environmental performance, the R^2 found was 0.205. When GM was added as the second antecedent, the R^2 increased by 0.16 to 0.365. Next, LM was also used as the first antecedent to operational performance, and the R^2 value of 0.29 was obtained. Again, GM was added as the second antecedent to operational performance and a 0.056 increase was noticed, yielding the R^2 of 0.346. Finally, when environmental performance was added as the third antecedent to operational performance, the R^2 increased to 0.510. The calculated t-values were greater than 1.96, indicating that these increments are significant at 0.05 level. Thus, the complementary between LM and GM results in a better environmental and operational performance compared to individual practices. Therefore, hypotheses H7 and H8 are supported. This agrees with Leong *et al*. (2019); (2020), who stated that integrating LM and GM practices yields improved environmental and operational performance.

4.3.3 Evaluating the mediatory role of the environmental performance function within the Lean-Green manufacturing sustainability complex

4.3.3.1 Introduction

Several studies have shown that implementing LM and GM on an individual basis has a positive impact on organisational performance. This knowledge is expanded by determining whether combining LM and GM influences organizational performance more than implementing them independently. It also examines whether being environmentally conscious has an impact on an organisation's social and economic performance. This study aims to investigate if improving environmental performance can help businesses enhance their economic and social performance. As a result, demonstrating that environmental compliance is not only a legal duty, but also a means of increasing social and economic performance. 782 questionnaires were issued to potential participants in the Zimbabwean Manufacturing industry. A total of 302 valid responses were received resulting in a response rate of 38.6%. The data was analysed using SEM in SMART PLS 3. The findings revealed that combining GM with LM improves economic, social, and environmental performance more than doing so independently. Furthermore, improved environmental performance resulted in improved social and economic performance. As a result, Lean-Green improves social performance by increasing worker health and safety labour and community relations.

4.3.3.2 Background

This research aims to investigate the mediatory role of environmental performance of organisations on their economic and social performances. It demonstrates that environmental compliance should not only be viewed as a requirement for compliance, but as a way of improving social and economic performances. The consideration, however, is if the environmental factor could have a more significant role, not just to the environment, but also in procuring economic and social capital for the organisations. This may translate to improved sustainable performance in the long run, and hence, the research question that;

RQ1: Does the improvement in environmental performance increase the economic and social performance of organisations?

It is crucial to demonstrate the role that environmental performance plays in improving economic and social performance to encourage organisations to improve environmental performance. Therefore, this research shows how environmental performance improvement can help organisations attain better sustainable performance. This can make manufacturing organisations to realise the importance of being environmentally compliant and motivate them to focus on environmental performance as equally as economic performance.

Sustainability covers organisations' role in satisfying human needs while preserving nature (Hasan and Ali, 2015). In this regard, organisations are adopting improvement techniques such as LM and GM. LM and GM have been implemented separately to improve organisational performance. Thus, the integration of these two methodologies can address issues around the social, economic, and environmental sustainability (Bhattacharya *et al.*, 2019).

Manufacturing industries have been adopting LM to improve resource utilisation and reduce waste (Farias *et al*., 2019). LM was initially developed in the quest to enhance the Japanese automotive company (Bento and Tontini, 2018). LM's goal is to reduce manufacturing waste and add value (Möldner *et al*., 2020). The non-value-adding activities are regarded as waste and need to be reduced. The value-added activities are what the customers are interested in and willing to pay for. A Lean organisation effectively and efficiently creates value to satisfy all its stakeholders (Fercoq *et al*., 2016). Thus, LM encourages organisations to be customer-focused through quality improvements, cost reduction, lead time reduction, and flexibility improvement (Fercoq *et al.*, 2016; Bhattacharya *et al.*, 2019; Ghobadian *et al.*, 2020).

Organisations must adopt techniques to reduce the usage of natural resources, minimise environmental waste, and reduce the negative environmental effects of their operations (Farias, *et al*., 2019). The concern about the environment has increasingly become important in economies and societies (Fercoq *et al*., 2016). Over the last few years, the world has experienced rapid industrialisation, which has improved people's quality of life while negatively affecting the environment (Ramos *et al.*, 2018). This has led to the emergence of the GM philosophy. GM is a method that seeks to minimise the negative effects caused by the products and services of manufacturing organisations while meeting the financial objective (Fercoq *et al.*, 2016). It reduces the waste generated by the manufacturing processes by applying techniques such as GP, LCA, and 3R.

A combined Lean-Green manufacturing allows organisations to develop better ways of operation. Therefore, organisations can adopt Lean-Green to evaluate and improve their 3BL performances (Leme *et al.*, 2018). Several researches that have been conducted evaluated the impacts of implementing LM or GM individually. Currently, researchers are beginning to investigate the relationship between LM and GM and how they jointly affect sustainability. Various authors have reported on the impact of Lean-Green on the 3BL, for instance, Hussain *et al*. (2019) in the United Arab Emirates (UAE) hotels, Huo *et al*. (2019) in China's manufacturing industries, and Thekkoote and Thekkoote (2022) in South Africa's SMEs. Others include Aminuddin *et al.* (2014), Tilina *et al.* (2014), Cai *et al.* (2019), Kovilage (2020). However, these researchers did not compare the impacts of combined Lean-Green implementation to those of their individual implementations. Thus, the current research investigates the combined impact of Lean-Green by answering the following research question.

RQ2: Does the joint implementation of LM and GM lead to better sustainable performance than when LM and GM are implemented individually?

This thesis aims to develop a Lean-Green assessment model that can be used to evaluate the impact of Lean-Green practices on sustainability using data collected in the Zimbabwe manufacturing industry. Zimbabwe is a developing country that is currently facing many economic challenges, including a high rate of inflation, which impedes the implementation process. In addition, like any other country, Zimbabwe is grappling with the effects of post Covid-19 pandemic. Since the beginning of Covid-19, the GDP of Zimbabwe has decreased by 8% (World Bank, 2021). Furthermore, there is no standard measurement model that the manufacturing companies can use to assess the impact of integrating LM and GM, and examining the role of environmental performance on economic and social performances. To the students' best knowledge, this is the first research that compares whether integrating LM and GM yields better results than when LM and GM are implemented individually, and also demonstrates the role of environmental performance in attaining enhanced economic and social performances.

4.3.3.3 Hypotheses development

To determine the impact of LM and GM on the three dimensions of sustainability, a second-order structural model was developed with LM and GM being the second-order latent variables. The first-order latent variables for LM are JIT, TQM, TPM and HRM, while the first-order latent variables for GM are LCA, 3R and GP. Previous research grouped the LM practices into four bundles, namely, JIT, TPM, HRM and TQM (Shah and Ward, 2003; Taj and Morosan, 2011; Bortolotti *et al.*, 2015; Arumugam *et al.*, 2020) hence, these practices were adopted for this study. On GM practices, Khan *et al.* (2019) used green purchasing, and Dawood and Abdullah (2017) used 3R to improve organisational performance. Also, LCA is the principal GM practice (Dües *et al.,* 2013). As a result, the student decided to adopt these GM practices.

Various studies have indicated that LM and GM are complementary in waste reduction (Dües *et al.*, 2013; Farias *et al.*, 2019). Also, Fercoq *et al.* (2016) stated that Lean practices are regarded as Green as they share the same objective of saving resources. Consequently, the research by Inman and Green (2018) on US manufacturing companies found that LM positively influences GSCM. Additionally, Green *et al.* (2018) applied JIT and TQM, and discovered that they have positive impacts on GSCM. Hence, it can be hypothesised that:

H1: LM has a positive influence on GM

LM's goal of eliminating wastes such as defects minimise environmental damage. LM is a method used to conserve resources, save energy and reduce pollution (Chugani *et al.*, 2017). Consequently, JIT plays an essential role in minimising pollution, waste and air emissions (Sajan *et al.*, 2017). A study in the US manufacturing industry concluded that LM has a positive relationship with environmental performance (Inman and Green, 2018). In addition, Green *et al.* (2018) applied JIT and TQM and realised improvements in environmental sustainability. Sajan *et al* (2017) applied LM in Indian SMEs and realised a great improvement in environmental sustainability. Thus, it can be hypothesised that,

H2: LM has a positive influence on environmental performance.

LM has an impact on economic performance which is attained through the improvement of operational performance measures such as cost minimisation, quality, productivity, flexibility improvement and inventory reduction (Nawanir *et al.*, 2020). In support, Pampanelli *et al.* (2014) pointed out that the main aim of LM is to improve the delivery, quality and reduce cost. Hartini and Ciptomulyono (2015) highlighted that LM is key on attaining improvement in sustainability performance, especially on economic performance. The research done by Sajan *et al.* (2017) concluded that LM positively impacts economic performance. Also, Baumer-cardoso *et al.* (2020) applied LM and reduced setup time and energy consumption leading to a significant decrease in costs. Hence, it can be hypothesised that,

H3: LM has a positive influence on economic performance.

GM philosophy aims to reduce the environmental damage by manufacturing companies through reduction in gas emissions, solid waste generation, use of hazardous material and generation of waste water (Green *et al.*, 2012). Mafini and Muposhi (2017) found that GM positively influences environmental performance. In addition, the results by Firmansyah and Maemunah (2021) supported the fact that GM improves the environmental performance of organisations. Rehman *et al.* (2013) developed and validated a GM framework that can be used to attain sustainability improvements through the implementation of GM practices. The application of GM practices in Ghana was found to positively influence environmental performance (Famiyeh *et al.*, 2018). Consequently, it was hypothesised that:

H4: GM has a positive influence on environmental performance.

Due to the increase in awareness on the safety and health of workers and community, the social performance dimension is increasingly being given attention (Afum *et al*., 2020a). The adoption of GM reduces environmental pollution such as waste water, greenhouse gas emissions and solid waste, thus increasing the health and safety of workers and communities. GM does not focus on improving environmental performance only, but also thrive to meet the expectations of the society (Sezen and Çankaya, 2013; Çankaya and Sezen 2019). The research conducted by Afum *et al*. (2020b) in Ghana manufacturing industry concluded that GM led to improved social performance. Another research by Afum *et al.* (2020a) pointed out that organisations can improve their social performance through the adoption of GM practices. Thus, we can hypothesise that,

H5: GM has a positive influence on social performance.

The investment in environmental sustainability issues such as reduction in energy, waste, material consumption and effluent is related to financial improvements (Sajan *et al.*, 2017). Sustainable environmental performance is associated with improvements in customer satisfaction, quality, profit, efficiency and responsiveness (Garza-Reyes, 2015). An improvement in environmental performance by organisations improves the company's image and customer satisfaction, thus impacting market performance (King and Lenox, 2001). In addition, reduction of waste, emissions, energy and material consumption, improves the health, comfort and relations with communities and workers (Sajan *et al.*, 2017). Consequently, improvement in workplace safety, employee health and working conditions increases the motivation and work rate of workers and subsequently, worker's productivity. Additionally, improving working conditions and workplace safety reduces the frequency of accidents, thus, reducing the fines for environmental accidents. Moreover, improved labour relations, community relations, health and safety compliance reduce complaints from workers and communities, which translates to less environmental fines. Therefore, it can be postulated that,

H6: Environmental performance is positively associated with economic performance.

H7: Environmental performance is positively associated with social performance.

H8: Social performance has a positive influence on economic performance.

LM and GM have been adopted separately to improve the performance of manufacturing companies. Researchers have recently started investigating the impacts of combining LM and

GM. When LM and GM are combined, they yield better results than when adopted individually (Fercoq *et al.*, 2016; Cherrafi *et al.*, 2018; Ramos *et al.*, 2018; Baumer-Cardoso *et al.*, 2020). Green *et al.* (2018) combined JIT, TQM, and GSCM and highlighted that when LM and GM practices are integrated, the impact is larger than when implemented separately. Hence, it can be postulated that:

H9: Integrated LM and GM have a greater impact on economic, social and environmental performance than when they are implemented individually.

The structural model developed is, therefore, shown in Figure 4.13.

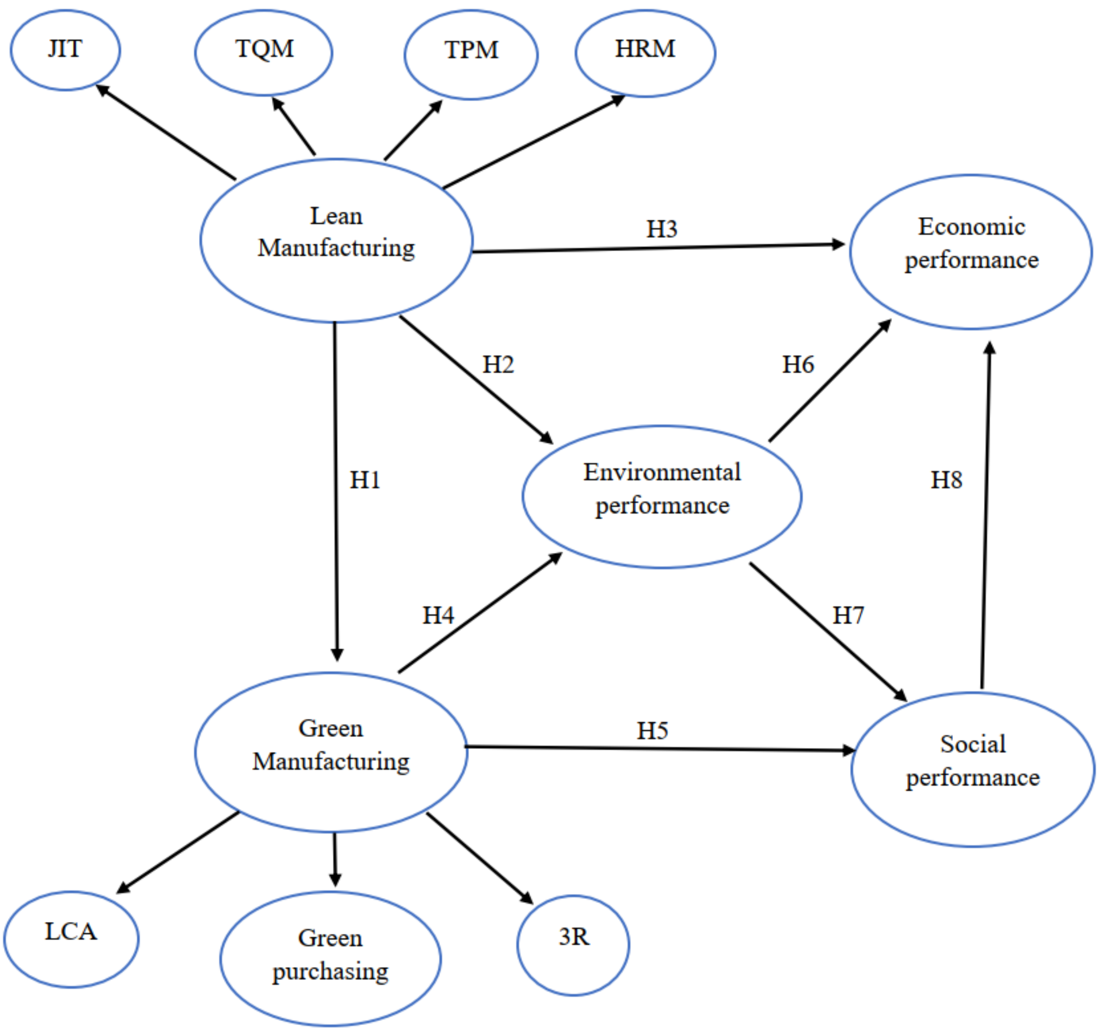

Figure 4.13: Conceptual model

4.3.3.4 Assessment of the measurement model

SEM was conducted using SMART PLS 3. Before the structural relationships could be evaluated, it was imperative to assess the reliability and validity of the data. Thus, the reliability and internal consistency were analysed using composite reliability and Cronbach's alpha, where values above 0.7 indicate high internal consistency and reliability (Nunnally, 1978). All the values for composite reliability and Cronbach's alpha were > 0.7, hence, they were acceptable. Moreover, the AVE was used to assess the convergence validity. According to

Fornell and Larcker (1981), the AVE values should be > 0.5. Accordingly, the values obtained were all > 0.5; therefore, they are considered acceptable. The reliability and validity results are indicated in Table 4.11

Table 4-11: R^2, AVE, Cronbach's alpha and composite reliability values

	Cronbach's Alpha	Composite Reliability	AVE	R^2
3R	0.873	0.902	0.569	0.636
Economic performance	0.914	0.932	0.663	0.603
HRM	0.727	0.830	0.550	0.294
Environmental performance	0.889	0.916	0.645	0.371
Green Manufacturing	0.925	0.934	0.508	0.366
Green purchasing	0.912	0.930	0.626	0.809
JIT	0.851	0.890	0.575	0.812
LCA	0.786	0.853	0.540	0.639
Lean Manufacturing	0.912	0.924	0.518	
Social performance	0.910	0.929	0.652	0.465
TPM	0.769	0.837	0.563	0.563
TQM	0.849	0.889	0.573	0.773

The discriminant validity of a construct indicates how it is truly distinct from the other constructs (Hair *et al.*, 2017; Famiyeh *et al.*, 2018). This study assessed discriminant validity using the Fornell-Larcker criterion, which compares the AVE square roots to the latent variables' correlations (Fornell and Larcker, 1981). The result, as shown in Table 4.12, indicates that discriminant validity was established as the AVE square roots were greater than their correlations with other latent variables (Famiyeh *et al.*, 2018).

Table 4-12: Fornell-Larcker criterion-discriminant validity

	3R	EP	EVP	GM	GP	HRM	JIT	LCA	LM	SP	TPM	TQM
3R	**0.754**											
EP	0.590	**0.814**										
EVP	0.638	0.675	**0.803**			0						
GM	0.708	0.486	0.595	**0.713**								
GP	0.515	0.262	0.402	0.699	**0.791**							
HRM	0.187	0.266	0.163	0.329	0.271	**0.742**						
JIT	0.393	0.496	0.415	0.548	0.454	0.512	**0.758**					
LCA	0.446	0.374	0.434	0.599	0.692	0.411	0.560	**0.735**				
LM	0.416	0.478	0.466	0.605	0.527	0.543	0.601	0.594	**0.720**			
SP	0.625	0.697	0.630	0.585	0.429	0.120	0.328	0.425	0.346	**0.807**		
TPM	0.299	0.217	0.329	0.462	0.438	0.538	0.64	0.401	0.641	0.197	**0.750**	
TQM	0.364	0.447	0.435	0.560	0.502	0.382	0.55	0.560	0.679	0.340	0.598	**0.757**

EP-Economic Performance, EVP – Environmental Performance, SP – Social Performance

4.3.3.5 Assessment of the structural model

VIF was used to determine collinearity among the factors. According to Hair *et al.* (2017), VIF values between 0.2 and 5 suggest there is no collinearity problem. Consequently, the VIF values ranged from 1.308 to 3.219, which were considered satisfactory. The coefficient for determination (R^2) highlights the portion of the variance of the endogenous variables explained by the model (Famiyeh *et al.*, 2018). An R^2 value of 26% is regarded as a large effect, 13% as a medium effect, and 2% as a small effect (Cohen, 1988). Figure 4.14 and Table 4.13 show that the model R^2 values indicated large effects in all its variables.

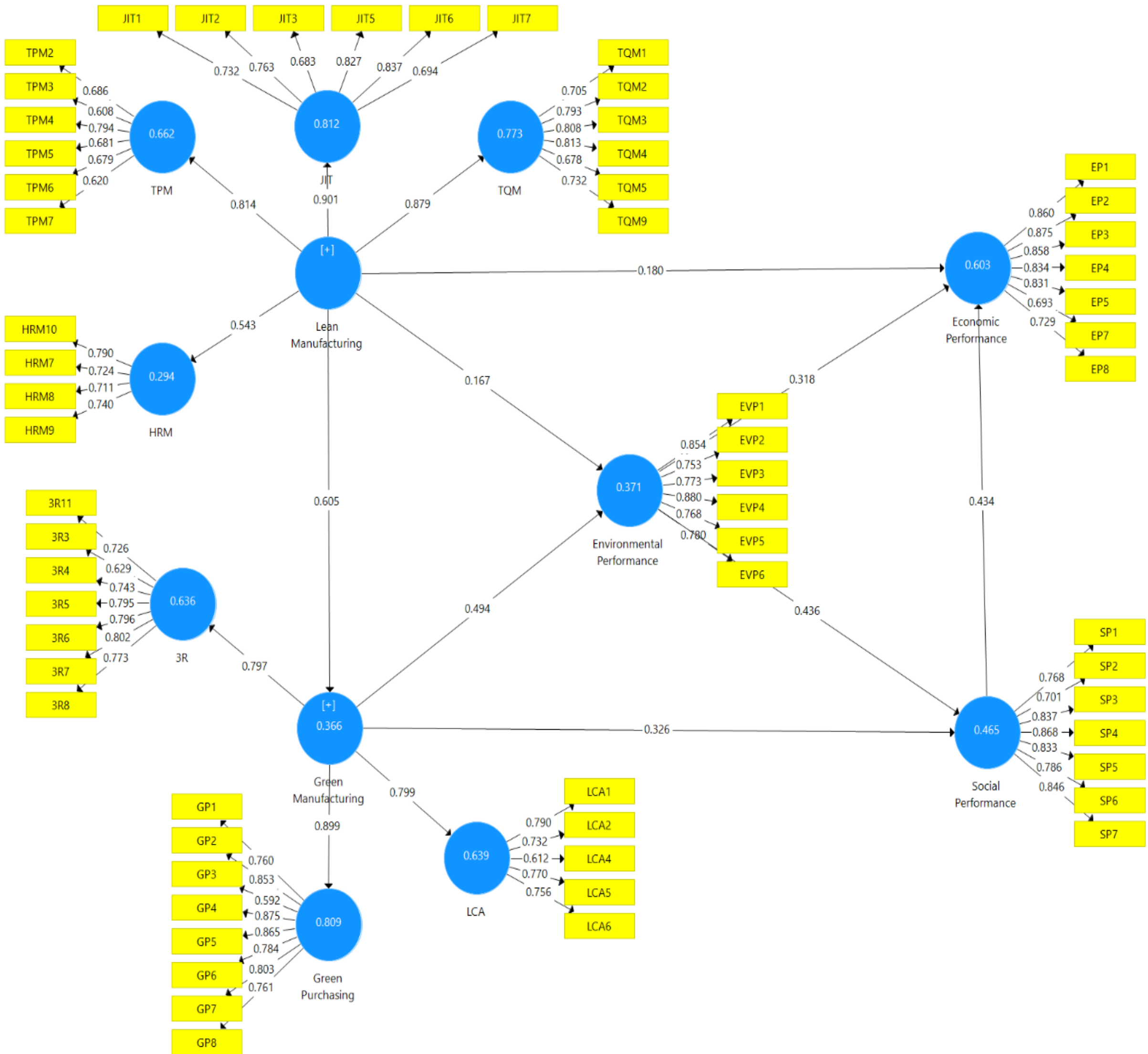

Figure 4.14: Structural model

The effect size (f^2) and Stone-Geisser (Q^2) values were used to evaluate the model (Famiyeh *et al.*, 2018). The f^2 effect represents the change in R^2 due to the omission of a specific exogenous variable (Cohen, 1988). f^2 value of 0.02 represents a small effect, 0.15 a medium effect, and 0.35 large effect (Cohen, 1988; Famiyeh *et al.*, 2018). The relationship between LM and GM, between social performance and economic performance, between environmental performance and social performance, and between GM and environmental performance all indicated large effects. Moreover, the relationship between LM and environmental performance, between LM and economic performance, between GM and social performance and between environmental performance and economic performance showed medium effects.

Q^2 was used to determine the model's relevant predictive power and to further examine the model accuracy (Geisser, 1974; Stone, 1974; Famiyeh *et al.*, 2018). The Q^2 values were determined through the blindfolding procedure in SMART PLS 3 using the omission distance (D) of 7. Q^2 values above zero for a specific reflective endogenous construct indicate a good predictive relevance (Maware and Adetunji, 2019b). The obtained Q^2 values were all > 0, hence the model had a good predictive relevance. Table 4.9 shows the f^2 and Q^2 values obtained in this research.

Table 4-13: Q^2 and f^2 values

	f^2				Q^2
	EP	EVP	GM	SP	
Social performance	0.385				0.293
Lean Manufacturing	0.164	0.152	0.578		
Green Manufacturing		0.356		0.229	0.139
Environmental performance	0.236			0.350	0.216

Figure 4.14 also shows the path coefficients of the model. Accordingly, environmental performance had a stronger direct relationship with GM than with LM as indicated by their path weights of 0.494 and 0.167 respectively. Also, environmental performance had a stronger direct relationship with social performance than with economic performance. Their path weights are 0.436 and 0.318, respectively. Indeed, LM also had a larger path weight with GM than environmental performance and economic performance, with path coefficients of 0.605, 0.167 and 0.180, respectively, also showing a strong relationship. Furthermore, the relationship between social performance and economic performance had a strong effect, as indicated by the path coefficient of 0.434. On the other hand, GM showed a stronger relationship with environmental performance than social performance, as indicated by the path weights of 0.494 and 0.326 respectively. The bootstrapping procedure was performed to determine the significance of the path coefficients using SMART PLS 3, adopting re-sample of 5000 runs (Hair *et al.*, 2017). A t-statistics value above 1.96 or a p-value less than 0.05 is considered significant. Table 4.14 shows that all the t-statistics and p-values were satisfactory; hence, the hypotheses were accepted. Therefore, both LM and GM have positive relationships with environmental performance. On the same note, environmental performance positively influences social and economic performance.

Table 4-14: Hypothesis testing results

	t-statistic	p-values	Hypothesis	Decision
EVP → EP	3.714	0.000	H6	Accepted
EVP → SP	4.799	0.000	H7	Accepted
GM → EVP	4.729	0.000	H4	Accepted
LM → EVP	1.984	0.031	H2	Accepted
LM → GM	8.208	0.000	H1	Accepted
SP → EP	5.942	0.000	H8	Accepted
LM → EP	2.194	0.029	H3	Accepted
GM → SP	3.612	0.000	H5	Accepted

A stepwise regression method was used to determine if the combined effect is stronger than individual impacts (Green *et al.*, 2018). LM and GM were regressed against environmental performance and the change in R^2 was noted. When LM was used alone, the R^2 values obtained were 0.203, 0.31 and 0.392 for environmental, social and economic performances, respectively. When GM was applied alone, the obtained R^2 values obtained were 0.262, 0.293 and 0.384 for economic, social and environmental performances, respectively. When GM was used as the second antecedent to LM, the R^2 values for environmental, social and economic performances increased to 0.371, 0.465 and 0.603, respectively. The calculated t-values were greater than 1.96, indicating that these increments are significant at the 0.05 level. Hence, the complementary relationship between LM and GM results in better sustainability performance compared to the individual techniques. Thus, hypothesis H9 is supported. This agrees with Leong *et al*. (2019) and Leong *et al*. (2020) who stated that the integration of LM and GM practices yields improved environmental and operational performance.

The Importance-Performance Map Analysis (IPMA) was conducted to determine the importance and performance of the predecessor latent variable using SMART PLS 3. The aim is to identify the predecessors with high importance but low performance so that they can be improved (Hair *et al.*, 2017). The performance for LM and GM were 62.9 and 60.7, respectively. The importance for LM was 0.729 and 0.827 for GM. The importance of both seems high, but their performances seem relatively medium. Thus, managers should devise possible ways of improving the performance of LM and GM so that better results are obtained.

4.3.3.5.1 Indirect impacts

To understand the importance of environmental performance on economic and social performance, the mediatory effects were analysed. As shown in Table 4.15, the results indicate that LM and GM have significant indirect effects on social performance and economic performance through environmental performance. Thus, environmental performance mediates the relationship between Lean-Green and socio-economic performance. This shows that those organisations seeking ways to improve their economic performance should consider improving their environmental performance.

Table 4-15: Indirect impacts results

	t-statistic	p-Values	Decision
LM ⟶ EVP ⟶ EP	1.967	0.04 2	Significant
LM ⟶ EVP ⟶ SP	1.994	0.033	Significant
GM ⟶ EVP ⟶ EP	2.822	0.005	Significant
GM ⟶ EVP ⟶ SP	2.980	0.003	Significant

4.3.4 A structural model for assessing the impact of Lean-Green barriers on sustainable performance

4.3.4.1 Introduction

Organisations have been implementing many techniques over the past few years to enhance their sustainable performance, amongst them are LM and GM. Organisations are currently combining these two approaches to maximise their combined benefits. Some have successfully managed to implement these two methodologies with the quest to improve their sustainable performance. However, despite successful implementation, Lean-Green barriers still prevent other organisations from achieving their stated goal. Therefore, organisations must be aware of and comprehend these barriers in order to avoid jeopardizing performance gains. Thus, this research attempts to investigate the influence of internal and external barriers experienced by companies post-implementation and how they affect their intended purpose of increasing sustainable performance. 302 valid responses were collected and analysed using SMART PLS. The findings demonstrated that both internal and external barriers prevent organisations from attaining their objectives and hence demand attention.

4.3.4.2 Background

This research aims to develop a model that can evaluate the degree to which the internal and external barriers affect sustainable performance of Zimbabwe manufacturing companies. Zimbabwe is a developing country facing many economic challenges, including a high inflation rate. Thus, identifying barriers helps the managers, stakeholders, and policy makers to prepare for such hurdles, and reduce the risks of failing to achieve their intended targets (Cherrafi *et al*., 2017b). During the implementation stage, a lot of resources are used; for example, financial resource is channeled towards employee training. Thus, on top of the failure to realise the improvements in performance, organisations can face a loss in resources that would have been used during the implementation process, hence, further burdening the manufacturing organisations that are already suffering from challenges like the effects of the Covid-19 pandemic. Thus, the research further explored how the internal and external barriers affect the relationship between social, economic, and environmental performance. According to the best knowledge of the student, no research has been conducted that developed a Lean-Green structural equation model to assess the relationships between Lean-Green barriers that are encountered post implementation and enhanced sustainable performance.

4.3.4.3 SEM for the Lean-Green barriers

4.3.4.3.1 Hypothesis development

To determine the impact of external and internal Lean-Green barriers, a second-order structural model was developed with Lean-Green Manufacturing being the second-order latent variable while LM and GM were the first-order latent variables.

Barriers have a negative influence on attaining improvements in sustainable performance. Mittal and Sangwan (2014) examined the impact of internal, economic, and policy barriers and concluded that internal barriers are the root cause of failures, and they should be tackled first. The research by Jabbour *et al.* (2016) showed that internal barriers have a negative influence on accomplishing improved green operational practices. Furthermore, Cherrafi, *et al.* (2017a) highlighted that the barriers, whether internal or external, equally affect Lean-Green Manufacturing. Thus, organisations need to understand these barriers so that they know how to prioritise them and manage the resources effectively and efficiently (Jabbour *et al.*, 2016; Kumar *et al.*, 2016; Cherrafi *et al.*, 2017a). Thus, it can be hypothesised that,

H1: External barriers negatively affect the impact of Lean-Green Manufacturing.

H2: Internal barriers negatively affect the impact of Lean-Green Manufacturing.

Several studies have indicated that the individual adoption of LM and GM leads to improvements in sustainable performance dimensions. For instance, a research conducted in the Indian manufacturing SMEs by Sajan *et al.* (2017) pointed out that LM has a positive influence on economic, environmental and social performance. Another study by Nawanir *et al.* (2020) also indicated that LM practices had a significant positive relationship with the three dimensions of sustainability. Research by Afum *et al.* (2020a) among Ghanaian SMEs found that GM positively affects these three dimensions of sustainability. Another research by Afum *et al.* (2020b) found that GM is positively related to economic, social, and environmental sustainability. According to Fercoq *et al.* (2016), integration of LM and GM yields better results than when implemented separately. In addition, Green *et al.* (2018) found out that the combined Lean-Green results in improved sustainability than when these methodologies are implemented individually. Therefore, it can be hypothesised that,

H3: Lean-Green Manufacturing is positively related to environmental performance.

H4: Lean-Green Manufacturing has a positive relationship with economic performance.

H5: Lean-Green Manufacturing has a positive relationship with social performance.

If waste, effluent, and air emissions are reduced, the health and comfort of workers and the community are improved, hence, the relationship between the organisations, communities and workers is enhanced. Environmental pollution causes tension between communities as their plants and animals may be affected. Inefficient waste management may cause health and social problems to both workers and communities (Sajan *et al.*, 2017). Thus, we can hypothesise that;

H6: Environmental performance has a significant and positive impact on social performance.

Investing in environmental sustainability issues, like the minimisation of energy consumption, waste, and material consumption is linked to financial gains (Sajan *et al.*, 2017). According to Li (2014) improvement in environmental performance is likely to reduce the cost of raw material and waste disposal leading to reduced production costs and improved financial performance. Furthermore, a reduction in non-value-adding activities, material and energy use, leads to economic benefits due to the reduction in operational costs (Sajan *et al.*, 2017). The application of environmental management techniques reduces the penalties for non-compliance (Afum *et al.*, 2020). In addition, improvement in environmental performance makes organisations realise improvements in quality, responsiveness, profit, efficiency and customer satisfaction (Garza-Reyes, 2015). This improves the company's image and market performance (King and Lenox, 2001). Sajan *et al.* (2017) found out that improved environmental sustainability leads to enhanced economic sustainability. Also, a study by Afum *et al.* (2020) in the Ghanian manufacturing industry found a positive relationship between environmental and economic performances. Therefore, we can postulate that,

H7: Environmental performance has a positive relationship with economic performance.

Improved working conditions and workplace safety reduce the frequency of accidents, resulting in reduced fines for environmental accidents. Furthermore, improved labour relations, community relations, health and safety, reduced worker and community complaints, and fewer environmental fines have an impact on the financial performance of organisations. Moreso, improved worker management reduces injuries, and mental and physical challenges, hence, the workers are motivated to perform better, leading to an improved production rate. Afum *et al.* (2020) found out that social performance has a positive influence on economic performance. Sila and Cek (2017) also established that social performance is the greatest contributor to economic performance. Furthermore, Barnett and Salomon (2012) found out that organisations that have large social performance attain higher financial performances. It can therefore be hypothesised that,

H8: Social performance is related to economic performance.

The relationships between the internal barriers, external barriers and 3BL are shown in Figure 4.15.

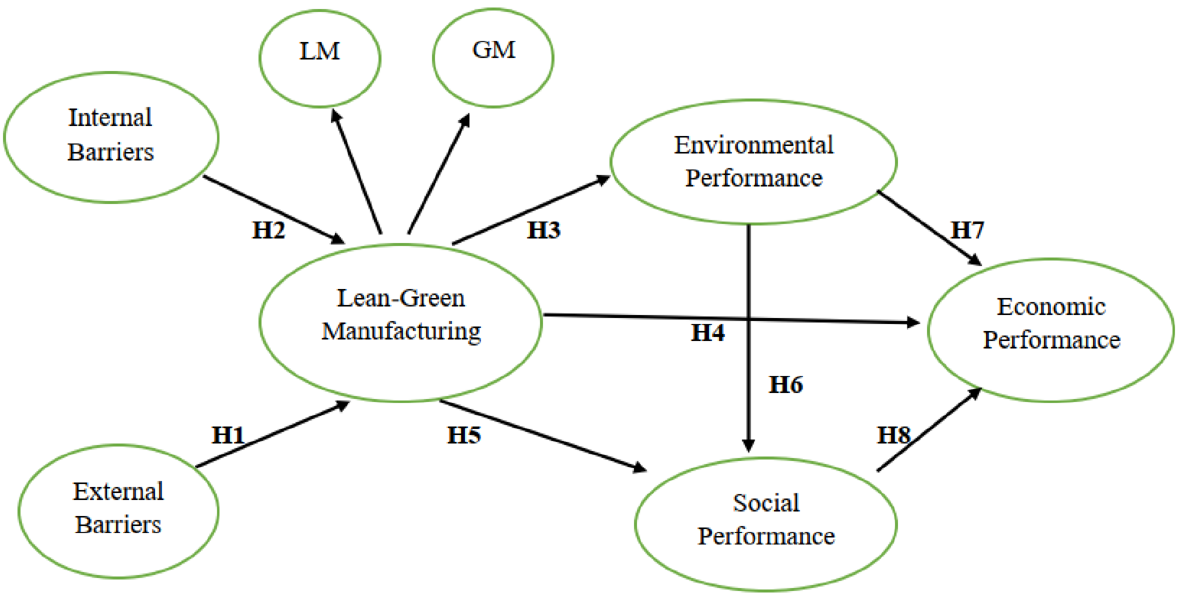

Figure 4.15: Conceptual model

4.3.4.3.2 Measurement scale analysis

SMART PLS 3 was used for Structural Equation Modelling to test the relationships between the factors. Before testing the relationships between the factors, the measurement model was assessed for validity and reliability. Cronbach's alpha and composite reliability were used to determine the internal consistency and reliability. The composite reliability and Cronbach's alpha values were higher than the recommended minimum value of 0.7 showing high internal consistency and reliability (Nunnally, 1978; Hair *et al.*, 2017). The convergent validity was determined using the AVE. Accordingly, the AVE values were all above the minimum recommended threshold value of 0.5, therefore, they were considered acceptable (Fornell and Larcker, 1981). Discriminant validity shows the extent to which a variable is truly distinct from the other variables of the model (Famiyeh *et al.*, 2018). The discriminant validity was analysed using the HTMT ratio. All the variables exhibited discriminant validity as all the HTMT values did not include 1. The results for Cronbach's alpha, composite reliability, AVE and discriminant validity are shown in Table 4.16.

Table 4-16: Cronbach's alpha, Composite reliability, AVE and HTMT values

	Cronbach's alpha >0.7	Composite reliability >0.7	(AVE) >0.5	HTMT
Economic performance	0.885	0.913	0.636	Does not include 1
Environmental performance	0.88	0.908	0.623	Does not include 1
External barriers_	0.866	0.908	0.712	Does not include 1
Green Manufacturing	0.888	0.909	0.529	Does not include 1
Internal barriers	0.841	0.88	0.513	Does not include 1
Lean Manufacturing	0.897	0.916	0.521	Does not include 1
Lean-Green Manufacturing	0.725	0.82	0.536	Does not include 1
Social performance	0.915	0.933	0.667	Does not include 1

4.3.4.3.3 Structural model evaluation

Collinearity among the factors was determined using the VIF. The VIF values ranged from 1 to 3.148. This indicates that the model had no collinearity problem as all the values were below the recommended maximum value of 5 (Maware and Adetunji, 2019b). The coefficient for determination (R^2) was also used for model assessment. According to Cohen (1988), Maware and Adetunji (2019a), R^2 of 0.26, 0.13 and 0.02 represents large, medium and small effects respectively. As shown in Table 4.17 and Figure 4.16, the model explained 28.5%, 30.9%, 81%, 83.2%, 83.6% and 60% of the variance in Lean-Green Manufacturing, environmental performance, economic performance, GM, LM, and social performance, respectively. This shows that the model explains large proportion of variance on all the variables.

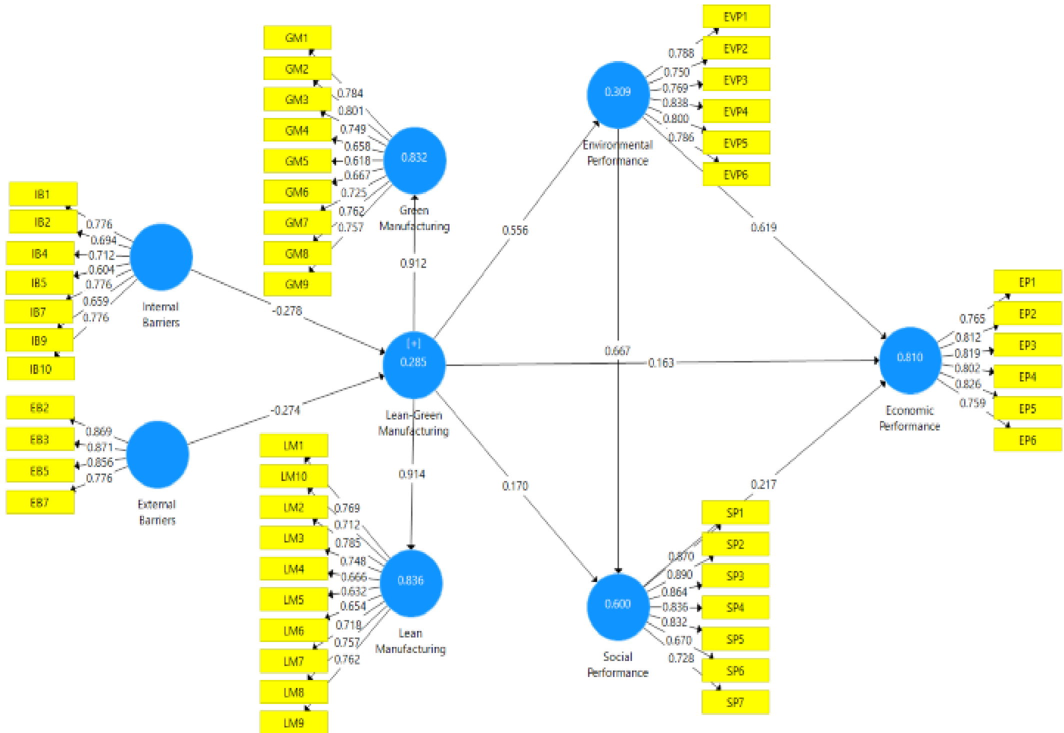

Figure 4.16: SEM structural model

Figure 4.16 also shows the path weights of the model. Accordingly, Lean-Green Manufacturing had a strong relationship with environmental performance compared to economic and social performance, as indicated by their path weights of 0.556, 0.163 and 0.170 respectively. The strength of the relationships between environmental performance and social performance and between environmental performance and economic performance are relatively the same as indicated by their path weights of 0.667 and 0.619, respectively. Also, the path weights of the relationship between internal barriers with Lean-Green Manufacturing and between external barriers with Lean-Green Manufacturing were -0.278 and -0.274 respectively, indicating that the strength of their relationships are relatively the same.

Table 4-17: R^2 and Q^2 values

Variables	R^2	Q^2
Economic Performance	0.81	0.493
Environmental Performance	0.309	0.172
Green Manufacturing	0.832	0.421
Lean Manufacturing	0.836	0.418
Lean-Green Manufacturing	0.285	0.114
Social Performance	0.6	0.372

The effect size (f^2) and predictive relevance (Q^2) values were used to further evaluate the model. The predictive relevance was determined using the Stone-Geisser's Q^2. To determine the Q^2

values, blindfolding method was performed in SMART PLS. The Q^2 values above 0 for a specific reflective endogenous variable indicate its predictive relevance (Famiyeh *et al.*, 2018). As shown in Table 4.18, the Q^2 values were higher than 0, indicating a large predictive relevance. In addition, the f^2 indicates how the R^2 values change due to the omission of a certain exogenous variable (Maware and Adetunji, 2019b). This indicates the effect of the omitted variable on the endogenous variable. The equation for measuring the f^2 is given by

$$f^2 = \frac{R^2 included - R^2 excluded}{1 - R^2 included}$$

According to Cohen (1988), Hair *et al.* (2017), f^2 effect values of 0.35, 0.15 and 0.02 indicate large, medium, and small effects, respectively. As highlighted in Table 4.14, the relationship between environmental performance and social performance, between environmental performance and economic performance, and between Lean-Green Manufacturing and environmental performance showed large effects, while the rest of the relationships showed medium effects.

Table 4-18: f^2 values

	Environmental performance	Economic performance	Social performance	Lean-Green Manufacturing
Environmental performance		0.788	0.767	
Social performance		0.263		
Lean-Green Manufacturing	0.448	0.159	0.189	
External barriers				0.208
Internal barriers				0.212

To determine the significance of the path coefficients, the bootstrapping procedure was performed in SMART PLS using re-sample of 5000 runs (Hair *et al.*, 2017; Famiyeh *et al.*, 2018). As shown in Table 4.19, the results indicate that internal and external barriers had a significant negative relationship with Lean-Green Manufacturing. Thus, when internal and external barriers increase, the chances of improving sustainable performance through Lean-Green implementation decreases. On the other hand, the results also show that Lean-Green Manufacturing has a significant positive relationship with social, environmental and economic performance.

Table 4-19: path coefficient, t-statistics, *p*-value and decision

Hypotheses	Effect of	On	Path coefficient	t-statistics	p values	Decision
H7	Environmental performance	Economic performance	0.619	9.883	0	Accepted
H6	Environmental performance	Social performance	0.667	9.635	0	Accepted
H1	External barriers	Lean-Green Manufacturing	-0.274	2.71	0.009	Accepted
H2	Internal barriers	Lean-Green Manufacturing	-2.78	2.76	0.007	Accepted
H4	Lean-Green Manufacturing	Economic performance	0.163	2.857	0.004	Accepted
H3	Lean-Green Manufacturing	Environmental performance	0.556	6.983	0	Accepted
H5	Lean-Green Manufacturing	Social performance	0.170	2.377	0.018	Accepted
H8	Social performance	Economic performance	0.217	2.519	0.012	Accepted

4.4 Chapter conclusion

This chapter highlights the results obtained from the mixed method. The results from the qualitative method shows the synergies and divergencies between LM and GM. Also, from the quantitative method, it was indicated that the implementation of Lean-Green has a positive impact on operational and environmental performance. Furthermore, environmental performance mediates the relationship between Lean-Green Manufacturing and socio-economic performance. Finally, internal and external Lean-Green barriers were found to negatively affect sustainable performance improvements.

Chapter 5: Discussion

5.1 Introduction

This chapter gives a detailed discussion of the results obtained. It also compares the results to the studies done by other scholars. Thus, it explains the results and their importance and relevance to manufacturing organisations. The discussion of the qualitative method is outlined first followed by that of the quantitative method.

5.2 Discussion of the results

Companies are adopting Lean-Green Manufacturing to improve operational performance while meeting the environmental obligation. However, the integration of Lean Manufacturing (LM) and Green Manufacturing (GM) is not always smooth, as there are contradictory issues. Thus, the research examined complementary and contradictory issues of Lean-Green to help organisations interested in integrating these techniques. The study indicated that LM and GM are complementary to one another, for example on waste reduction, lead time reduction, employee involvement and customer focus. Also, when LM and GM are combined, better improvements are realised than when one of the methodologies is implemented. This agrees with research conducted by Green *et al*. (2018), who found that when LM and GM are combined, the improvement is more significant than when implemented separately. In addition, Fercoq *et al*. (2016) noted that Lean companies that are adopting GM are attaining better Lean results than those that are not. Furthermore, Haddach *et al*. (2017), Cherrafi *et al*. (2018), Logesh and Balaji (2020), Afum *et al*. (2021) highlighted that improved GM results are attained by the reduction of Lean waste and adoption of LM practices. This agrees with Dües *et al*. (2013), who highlighted that LM acts as a catalyst toward attaining GM, thus, further confirming the synergistic effect.

The results also agree with Dües *et al*. (2013) as they show synergies in supply chain management, application of waste reduction techniques, and people involvement, amongst others. Both researches also agree that there are some divergencies between LM and GM, for example, their focus, principal tools, and end-of-life approach. However, the current research extends this knowledge by adding some complementary and contradicting issues between LM and GM. The synergies include that they both include long term thinking, aim to add value, and improve sustainable performances. Some noted divergencies include how they define value, their contribution to sustainability, and their approach towards competitiveness and profit.

Although the research highlighted that LM affects economic and social performance while GM affects environmental performance (Pampanelli *et al*. 2016), the research done by Sajan *et al*. (2017) indicated that LM has a positive impact on social, economic, and environmental performance. In their research, Afum *et al*. (2020a; 2020b) found out that GM has a significant positive impact on all three dimensions of sustainability. Thus, this further highlights that the integration of LM and GM enhances organisational performance.

The research also agrees with Dües *et al*.(2013) as they both noted that the greatest contradicting concern is the divergence between Just in Time (JIT) delivery and increased greenhouse gas emissions. Some strategies for resolving these contradicting issues include selecting suppliers who are geographically close together so that they can share the load during deliveries. Venkat and Wakeland (2006) advocated that the emissions can be reduced by sharing trucks with other products and companies and using heavy-duty trucks. Also, optimisation of the vehicle routing system can be beneficial, as the shortest routes are identified and used during deliveries. Additionally, routes with less traffic congestion can be utilised to minimise the emissions (Kim *et al*., 2009). Furthermore, routes for delivering products to customers can be managed so that each truck focuses on customers in the same geographical area. Also, if the suppliers and the customers are in the same geographical area, emissions can be reduced due to the shorter distance travelled. However, as the travel distance increases, the conflicting nature increase due to increased gas emissions. In addition, Lindblom and Stenqvist (2007) pointed out that the use of either sea transportation or a combination of sea and road transportation can reduce CO_2 emissions.

This study also investigated the impact of adopting LM and GM on the environmental and operational performance of manufacturing companies in Zimbabwe. Lean-Green has emerged as a new and essential manufacturing philosophy that can be adopted by manufacturing companies to achieve competitive advantage (Basha *et al*., 2020). In addition, the renewed focus on environmental requirements by regulators and customers has pushed organisations to reduce environmental pollution by adopting techniques such as Lean-Green (Huo *et al*., 2019). Recently, researchers are beginning to explore the relationship between LM and GM and how they mutually affect organisational performance, but there is still a lot of opportunities for research in this area, especially in developing countries where it does not seem to be any work of this nature done.

Many manufacturing companies seemed hesitant to implement Lean-Green. They are unsure which practices to implement and the benefits of such implementations. Therefore, this research tackles this by providing evidence of the benefits of implementing Lean-Green practices. The results support the assertion that when integrated, LM and GM positively impact environmental and operational performance. LM was found to directly impact both environmental and operational performance. This is consistent with earlier studies such as (Green *et al*., 2018; Inman and Green, 2018). Earlier studies also reported a positive relationship between LM and environmental performance (Ghobakhloo *et al*., 2018; Green *et al*., 2018). The impact of LM on operational performance is also supported by (Jabbour *et al*., 2013; Nawanir *et al*., 2013; Godinho *et al*., 2016; Maware and Adetunji, 2019a; Hassan and Jaaron; 2021; Buer *et al*., 2021; Saini and Singh, 2022). In contrast, the research by Khalfallah and Lakhal (2020) highlighted that Total Quality Management (TQM), JIT and Total Productive Maintenance (TPM) do not have a positive influence on operational performance. Although LM had a positive relationship with environmental performance, the indirect impact through GM is stronger compared to the direct impact. This shows that LM and GM are complementary. GM was found to have a positive relationship with environmental performance. This agrees with the study conducted in the Indonesian manufacturing and logistic industry (Firmansyah and Maemunah, 2021). The results failed to support the hypothesis that GM has a positive relationship with operational performance. Nevertheless, it was depicted that GM has an indirect impact on operational performance through environmental performance. This is consistent with the US firms' survey (Inman and Green, 2018). Thus, the enhancement of operational performance is not directly caused by implementing GM but by improving environmental performance due to adopting GM practices. On the same note, environmental performance was found to positively affect operational performance. This is also supported by Jabbour *et al.* (2013). More importantly, the integration of LM and GM showed a greater impact compared to the implementation of GM and LM separately. This agrees with earlier studies who noted that combining LM and GM practices yields better results than implementing one of the methodologies (Fercoq *et al.*, 2016; Cherrafi *et al.*, 2018). This was also confirmed by Ramos *et al.* (2018) who noted that LM acts as a catalyst for attaining better Green improvements. Generally, the integration of LM and GM supports the improvement in environmental performance leading to improved operational performance. Lean practices aim to reduce the non-value-adding operations thereby increasing efficiency (Firmansyah and Maemunah, 2021). On the other side, GM aims to improve environmental performance by eliminating environmental waste (Firmansyah and Maemunah, 2021, Singh, 2021).

The manufacturing industry plays a vital role by contributing to the growth of the economy and creating employment. Although rapid industrialisation has contributed to the growth of economies, the consequent massive environmental damage has resulted in a decrease in environmental and social sustainability. Hence, manufacturing companies are adopting improvement methodologies such as LM and GM. Various studies have reported on the improvements achieved by implementing LM (Hartini and Ciptomulyono, 2015; Longoni and Cagliano, 2015; Sajan *et al.*, 2017; Nawanir *et al.*, 2020) and GM (Acharya *et al.*, 2014; Afum *et al.*, 2020a; Rehman and Yu, 2020; Singh, 2021, Al-Hakimi *et al.*, 2022) on sustainability. However, this research extended this knowledge by investigating the impact of being environmentally compliant on social and economic performances. The improvement of environmental sustainability has shifted from being optional to mandatory (Acqah *et al.*, 2021). Hence, organisations have been implementing GM in quest for better environmental performance. The findings indicated that improving environmental performance results in better economic and social performance of the manufacturing organisations. This agrees with the results obtained by Sajan *et al.* (2017) on the LM model in Indian SMEs and Afum *et al.* (2020b) on the GM model in Ghana's manufacturing industry. Though organisations are usually more interested in their economic performance, they should know that this can be improved through improvements in environmental performance. In particular, the findings showed that environmental sustainability is key in attaining improved socio-economic performances. Therefore, sustainable performance can be achieved through the realisation of good performance in the environment. Furthermore, the study showed a positive influence of social performance on economic performance, which agrees with results obtained by Afum *et al.* (2020a) on a GM model. Although the positive relationship between social performance and economic performance contradicts the findings by Sajan *et al.* (2017), achieving social improvement means workers are healthy and available for work, their safety is guaranteed and conflicts are reduced, thus, they are motivated and encouraged to perform better.

Also, the research investigated whether the combined implementation of LM and GM yield better improvements in the Triple Bottom Line (3BL) than individual implementation. It was found that when LM and GM are implemented simultaneously, their impact is stronger than when they were adopted separately. This agrees with several authors who have noted that integrated LM and GM yield better results than when implemented individually (Fercoq *et al.*,2016; Cherrafi *et al.*, 2018; Green *et al.*, 2018; Ramos *et al.*, 2018). This shows that Lean-Green is a valuable methodology for attaining social, economic, and environmental performance improvements. These findings agree with several studies that have reported on the impact of implementing Lean-Green on environmental performance (Green *et al.*, 2018; Inman and Green, 2018). However, Chen *et al*. (2019) found out that the relationship between Lean practices and environmental performance is not supported as the Lean practices positively impact specific environmental performance measures and not the overall environmental performance. Furthermore, Hartini and Ciptomulyono (2015) pointed out that issues on social performance have not been widely examined. Hence, the results of this study are more important as, in addition to economic and environmental performances, it outlines how social performance is improved by implementing Lean-Green. Thus, it focuses on the people (social) in addition to profit (economic) and the planet (environment). It includes safety and health of workers, labour relations and community engagement.

Organisations worldwide are striving to be sustainable, hence, they are adopting various methodologies such as LM and GM. Researchers have been investigating the impact of integrating LM and GM to enhance sustainable performance (Al-Hakimi *et al*., 2022; Antony *et al*., 2022). This study investigated how the Lean-Green barriers hamper organisations from achieving their goal of improving sustainable performance. Results have shown that both internal and external barriers hinder organisations from achieving the target results. Both internal and external barriers were found to have significant negative impact on Lean-Green Manufacturing. As the significance of the barriers increases, the chances of organisations being able to attain their target diminishes. Also, the results of this research have shown that both external and internal barriers have relatively equal and negative impact on Lean-Green Manufacturing. This contradicts the results obtained by Jabbour *et al.* (2016) in Brazil, who showed that only internal barriers have a significant negative impact on Green operations and not external barriers; hence manufacturing organisations in Brazil are making efforts to improve their internal activities compared to those in Zimbabwe. Also, compared to Brazil, Zimbabwe encounters high socio-economic challenges, including high inflation rate signifying that it faces many external barriers. Internal barriers related to humans; for example, lack of training and education, lack of awareness and lack of top management commitment, are key to attaining sustainable development. Workers need to be trained, involved and encouraged to establish a favourable organisational culture (Jabbour *et al.*, 2016; Thanki, 2018). Overcoming the financially related internal barriers, such as financial constraints and ineffective technology, is also important for organisations to realise improvements in sustainable performances. Organisations need to source resources and allocate them appropriately as improper allocation can cause failures (Thanki, 2018). In addition, overcoming external barriers related to the government, for example lack of government support, is also critical for Lean-Green to achieve its intended goal as some organisations have inadequate resources.

Companies that have successfully implemented Lean-Green Manufacturing should understand that even after the implementation process, they can still face challenges that can hinder them from attaining their intended goal. Thus, this enables them to allocate resources accordingly.

Therefore, managers should devise ways to address the internal barriers as they are related to policy and economic activities (Mittal and Sangwan, 2014). Understanding the internal barriers will help organisations to eliminate those barriers within their capacity before focusing on external barriers. In addition, knowledge of external barriers will enable organisations to engage with the respective authorities. Additionally, the results of this research have demonstrated the relationship between environmental, social, and economic performance. Thus, by minimising the internal and external barriers, enhanced environmental, social, and economic performance is attained.

5.3 Chapter conclusion

This chapter discusses the results of the study. It was found that the results obtained in this study agrees with a lot of other studies. Moreover, the results from the qualitative method agree with those from the quantitative method as they both demonstrated that LM and GM can be combined to enhance the performance of organisations.

Chapter 6: Conclusion, implications, and future research opportunities

6.1 Introduction

This chapter gives the conclusion to the research. This is achieved by answering the research questions. In addition, it gives practical, managerial, and social implications. Moreover, the limitations of the research are outlined as well as the future research opportunities.

6.2 Conclusion

The study investigated the implementation of Lean-Green manufacturing using the Population, Intervention, Comparison, Outcome (PICO) method. 141 papers focusing on Lean-Green manufacturing were used to identify the complementary and contradictory issues. The results showed that Lean Manufacturing (LM) and Green Manufacturing (GM) are complementary as they all aim at eliminating waste to satisfy the customers. As a result, they aim at continuous improvement, lead time reduction and supply chain improvements through the application of various waste reduction practices and the involvement of employees. However, LM and GM differ in the way they define waste, what their customers are interested in, the practices, and emission reduction, amongst others. Furthermore, it was highlighted that LM aims to improve operational performance while GM is interested in environmental performance.

In addition, the results from this study were further compared to those obtained by Dües *et al*. (2013). The results were in agreement, and they both indicate related divergencies and synergies of LM and GM. In addition to Dües *et al*. (2013), this study showed that LM wastes can be extended from 7 to 8. Furthermore, issues of sustainability, value creation, competitiveness and profit were also highlighted. In addition, implementation barriers, drivers, Critical Success Factors (CSFs), synergies and divergencies, impact on performance and integration with other techniques were found to be the research themes. Thus, knowledge of themes, complementary and contradictory issues on Lean-Green does not benefit manufacturing industries only, but it is useful for other industries such as mining and construction.

The study has indicated the complementary and contradictory areas of LM and GM. This will help those organisations willing to adopt Lean-Green on what to expect. It further assists those who are unsure, which method to implement first, LM or GM, to consider implementing them simultaneously. Furthermore, the positive impacts of the integration outweigh the negative effects, thus, making it clear for those organisations that are not sure of what Lean-Green can bring to them.

Furthermore, this research examined the impact of implementing Lean-Green practices on organisational performance. The research objective was to shed more light on the impact of Lean-Green in a developing country and assist those organisations that worry about adopting such methodologies. Particular attention was given to environmental and operational performance. The data was collected in the Zimbabwean manufacturing industry and analysed using SMART PLS. It was discovered that Lean-Green has an impact on operational and environmental performance. Additionally, integrating LM and GM practices has a significant influence compared to LM and GM being implemented separately. Thus, those organisations that have already implemented LM should consider integrating it with GM to attain pronounced benefits.

In addition, the research investigated how improvements in environmental performance affect economic and social performance. The results demonstrated that environmental performance is crucial in achieving enhanced social and economic performance. Thus, it is not sufficient for organisations to view the adoption of environmental management techniques as a compliance issue, but it's a necessity to drive their bottom line and gain social capital, which also feeds back to economic gains. In addition, the study compared the impact of the simultaneous implementation of LM and GM and individual implementation. The combined impact of LM and GM was found to be greater than the individual impact. Hence, organisations should consider implementing both methodologies simultaneous instead of implementing one of the methodologies. Although adopting Lean-Green is associated with implementation costs, there are a lot of benefits associated with such implementations.

Lastly, the study also investigated the impact of internal and external Lean-Green barriers post implementation phase and how they affect the improvements in sustainable performance. The results showed that both the internal and external barriers have negative relationships with sustainable performance. Thus, by reducing these barriers, organisations are likely to attain improvements in sustainable performance. Hence, organisations should understand these barriers and devise ways to overcome them.

6.3 Research implications

6.3.1 Managerial implications

The research has demonstrated that Lean-Green positively impacts environmental and operational performance, therefore, the managers have been provided with knowledge on the benefits of integrating LM and GM. Particularly, the managers understand the relational paths of Lean-Green and their impacts on organisational performance, and consequently, the focus needs not only be on the direct impact, but the total impact. In addition, the study showed that, although implementing Lean-Green requires resources, there are a lot of benefits associated with such implementations. Thus, the managers of manufacturing organisations should strive to implement Lean-Green and enjoy the benefits of such implementations. Furthermore, managers can benefit from reducing costs due to the elimination of waste and improvement in environmental sustainability. Hence, organisations can satisfy both Lean customers and Green customers as all their requirements will be fulfilled, thus, increasing competitiveness.

Most studies that have been done focused on the impact of implementing LM and GM separately. As a result, it seems managers are not sure of the actual impact of the simultaneous implementation of LM and GM, and how it yields better results relative to the individual implementation of each. This study, however, bridges this gap by comparing the impact of simultaneously implementing LM and GM to their individual implementation, and the pattern of achieving this result, especially the indirect paths. Also, this research has demonstrated that GM may not have a direct impact on operational performance, but the relationship that is indirect through environmental performance is significant. Also, the indirect impact of LM on environmental performance through GM provides further reinforcement of performance improvement. As a result, managers should know that to attain enhanced operational performance and improve competitiveness, there is a need to improve environmental performance through GM implementation. In addition, they now know that Lean-Green has a positive impact on companies regardless of where they operate within the supply chain.

The research has shown that environmental, economic, and social performance can be improved by adopting Lean-Green manufacturing. Furthermore, the combined Lean-Green was found to have a greater impact on the Tripple Bottom Line (3BL) than when LM and GM are implemented individually. Therefore, for organisations seeking to be sustainable, their managers should consider implementing LM and GM simultaneously. Additionally, the research has demonstrated that improvements in environmental performance has a positive impact on social and economic performances. This furnishes managers with evidence of the importance of being environmentally compliant. Moreso, those skeptical organisations yet to implement either of the methodologies should consider doing so, as such implementations are not a waste of money but are associated with many benefits.

Furthermore, the Importance-Performance Map Analysis (IPMA) has shown that LM and GM are important methodologies that need to be correctly implemented to enhance performance. However, the implementation of these methodologies may be associated with high costs; hence, managers should consider this.

While synergies and divergences between LM and GM were noted, divergence on CO_2 emissions is concerning, hence, organisations seeking to integrate LM and GM should devise ways to tackle it. The research equips managers with knowledge about Lean-Green barriers, implementation drivers, impact on performance, CSFs, and how Lean-Green integrates with other methodologies. Knowledge of Lean-Green barriers will help managers understand the hurdles they are likely to face when integrating LM and GM. Also, understanding the drivers that push organisations to integrate LM and GM will equip them with knowledge of why other companies are opting to integrate LM and GM, hence they can make informed decisions. In addition, knowing and understanding the CSFs, will help managers to reduce the risk of unsuccessful implementations that can result in loss of organisational resources. Successful implementation of Lean-Green improves organisational performance, resulting benefits, and integrating Lean-Green with methodologies such as Agile manufacturing and Six Sigma enhances organisational performance of companies. Therefore, before organisations begin the process of integrating LM and GM, they need to know and understand the Lean-Green barriers, implementation drivers, its impact on performance, CSFs and how Lean-Green can be integrated with other methodologies so that they make informed decisions.

6.3.2 Social implications

Traditional manufacturing methods tend to cause many negative environmental effects such as increased carbon footprint, waste and energy consumption. However, socio-environmental issues are of great concern nowadays, with stakeholders, policy makers, communities, and customers demanding organisations to adopt environmentally friendly sustainable manufacturing (Ghobakhloo *et al*.,2018). Therefore, implementing Lean-Green will reduce the negative environmental impacts caused to the societies, thereby improving the relationship with communities. The research demonstrated that the integration of Lean-Green has a positive relationship with social sustainability. Lean-Green leads to a reduction in pollution by solid waste, waste water and air emissions. Therefore, less environmental damage is caused to the nearby communities and working environment, thus likely improving the relationship with the communities, as well as the health and safety of workers.

This research also demonstrated that both LM and GM positively impact environmental performance. The indirect impact of LM on environmental performance through GM is greater than the direct impact. Hence, organisations thinking of implementing LM alone should consider integrating it with GM for enhanced environmental performance. Improvements in environmental performance mean less environmental harm is caused to the communities and workplaces, thus probably improving the safety and health of workers and communities.

6.3.3 Research limitations and future research opportunities

The first part of the research was based on a literature review, therefore, it only gives a summary of results obtained by other researchers. It only focused on Lean-Green in general, and it did not narrow down to a specific country or a particular type of manufacturing industry. It may be interesting to explore how Lean-Green can be implemented at the country level. The socio-economic and political environment differs from one country to another; thus, the Lean-Green requirements and implementations differ. Therefore, companies need to examine how best to integrate LM and GM based on their country. Furthermore, the study only focused on manufacturing companies and did not consider other industries such as service, agriculture, and construction. Hence, the study can be extended to other types of industries. Additionally, this study discussed the relationship between selected Lean and Green practices. In future, organisations can determine the practices that are more applicable to them and use those in such research.

The other parts of the research were conducted through a survey of the manufacturing companies in Zimbabwe only. Although Zimbabwe is a developing country, the business environment differs from one country to another, hence the results may not be simply extrapolated for manufacturing companies in other developing countries. Furthermore, Zimbabwe is under socio-economic challenges characterised by a high rate of inflation; hence some of the barriers maybe be confined to the Zimbabwean situation. Thus, similar research can be conducted in other developing countries and results compared with those obtained in this study.

A comparison can be done between Small and Medium Enterprises (SMEs) and large enterprises, as SMEs seem to be lagging due to several reasons, such as financial constraints. The research can investigate if the size of the organisations can play a moderating role on the impact of Lean-Green on environmental performance.

6.4 Chapter conclusion

This chapter focused on outlining the research conclusion by answering the research questions. Also, the implications of the research to the society and organisations were indicated. This will help organisations to prepare accordingly. Furthermore, the limitations and future areas of research were outlined. This will guide future researchers in identifying possible research areas and ways to eradicate the limitations faced in this research.

6.5 Thesis summary

The Table below indicates the summary of the novel contributions, made in each chapter of the research and how it relates to the research questions.

Table 6-1: Summary of the thesis

Chapter	Contribution
1	Introduces the thesis and outlines the research questions that were answered in this research.
2	Outlines the literature on LM and GM. It outlines the research gap and how it led to the formulation of the research questions.
3	Outlines the qualitative and quantitative research methods that were used in the research.
4	Provides the answers to the research questions.
5	Is the discussion of the results which provided a detailed outline of the answers to the research questions.
6	The chapter outlines the research implications and provides future research questions which can be answered by further research.

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Appendix 1
Cover letter for PhD questionnaire survey

Name: Tinotenda Machingura

University: University of Pretoria

Address: University of Pretoria

Department of Industrial and Systems Engineering
Engineering building 2
Level 3
University of Pretoria
Lynnwood Road
Private bag X20 Hatfield
Pretoria
0028

Dear Respondent

I am a PhD student at the University of Pretoria in the Department of Industrial and Systems Engineering. I am conducting research titled: The impact of Lean-Green Philosophy on Zimbabwean manufacturing industry. The research aims to develop a model to measure the success of Lean-Green manufacturing deployment. This survey is designed to measure the impact of Lean-Green manufacturing implementation on organizational performance. I believe that the measurement model will help new adopters of Lean-Green Manufacturing anticipate and assess Lean-Green manufacturing's impact on their organisational performance. This survey is anonymous, and the responses will only be used for research purposes. The questionnaire will take about 20 minutes to complete.

Thank you for the time and effort to complete the questionnaire.

Sincerely

Tinotenda Machingura

(PhD student in Industrial and Systems Engineering)

Section A: company profile

A1. Job title/ position________________________ A2. Years in this position____________

A3. Years in the organization___________________

A4. What is the company's main business activity?

☐ Food and Beverage ☐ Chemicals and Petrochemicals

☐ Plastic and Rubber ☐ Pharmaceutical

☐ Agrochemical ☐ Wood and Furniture

☐ Electronics and Electrical ☐ Fertilizer

☐ Textiles ☐ Leather

☐ Paper ☐ Other, specify________________

A5. How many employees does your company have?

☐ under 41. ☐ between 41 and 75. ☐ between 76 and 150.
☐ between 151 and 250. ☐ between 251 and 350. ☐ over 350.

Section B: Impact of Lean constructs on organisational performance.

Indicate the level of agreement or disagreement with the statement given that it describes the level of adoption of Lean manufacturing practices in your organisation.

1= Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Item	Rating				
	1	2	3	4	5
Our workers undergo cross-functional training.					
The suggestions of the team members are considered before making decisions.					
Our shop floor employees are key to problem solving.					
Our workers are involved in continuous improvement efforts.					
My firm has multifunctional (multiskilled) workers.					
My firm gives workers a broader range of tasks.					
At our firm, we have an expansion of autonomy and responsibility.					

	1	2	3	4	5
The workers are given incentives and annual bonuses for the process improvement.					
In our company, the management takes all improvement suggestions seriously.					
The employees are encouraged to work together to achieve common goals.					
Our operators are trained to maintain their own machines.					
Our equipment is always in a high state of readiness.					
We keep the records of routine maintenance.					
We maintain all our equipment regularly.					
We dedicate a portion of everyday to planned equipment maintenance related activities.					
The equipment maintenance records are shared with all the shop floor employees.					
Our operators understand the cause and effect of equipment deterioration.					
Our operators inspect and monitor the performance of their own equipment.					
Our operators can detect and treat abnormal operating conditions of their equipment.					
Our customers receive just-in-time deliveries from us.					
Our suppliers deliver to us on a just-in-time basis.					
Our company involves all the key suppliers in the process.					
Our company has a formal supplier certification programme.					
The daily production schedule is met every day.					
The daily production schedule is completed on time.					
The layout of our shop floor facilitates low inventories and fast throughput.					
Our equipment or processes are under statistical quality control.					
We use statistical techniques to reduce variance.					
Control charts are used to determine whether the manufacturing processes is in control.					
The processes in the plant are designed to be “foolproof.”					
The process ensures that all parts, materials, information, and resources meet the specifications before use.					
Our customers give us feedback on our quality and delivery performance.					
We undertake programs for quality improvement and control.					
Our shop-floor employees are authorized to stop production for quality problems.					
Quality problems can be traced to their source and solved without reworking too many units.					

Section C: Impact of Green constructs on organisational performance.

Indicate the level of agreement or disagreement with the statement given that it describes the level of adoption of Green manufacturing practices in your organisation.

1= Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Item	Rating				
	1	2	3	4	5
Our company recycles materials.					
Our company reuses materials.					
We optimize the processes to reduce solid wastes.					
We optimize the processes to reduce water use.					
We optimize the processes to reduce air emissions.					
We optimize the processes to reduce energy use.					
We optimize the processes to reduce raw material use.					
We design the products for reduced consumption of raw material.					
We design the products for reuse, recycle, recovery of material.					
We design the products to avoid or reduce the use of hazardous products and process.					
We design the products for reduced consumption of energy.					
New product designs are thoroughly reviewed before the product is produced and sold.					
We coordinate with the suppliers for environmental objectives.					
We perform the environmental audit for suppliers' internal management.					
Our suppliers are ISO14000 certified.					
We choose our suppliers by environmental criteria.					
We urge/ pressure our supplier(s) to take environmental actions.					
We provide the design specification to suppliers that include environmental requirements for purchased items.					
Our products are eco-labelled.					
Our firm has an environmental purchasing policy in practice.					
We systematically consider customer feedback for eco-design.					
Our company considers its discharges as a wealth.					
We possess a system of recovering and reutilizing end-of-life products.					
We recover the company's end-of-life products.					
We consider the impact of products in their entire lifetime.					
We monitor the environmental impact of the products at all stages.					

Section D: Impact of Lean-Green constructs on organisational performance.

Indicate the level of agreement or disagreement with the statement given that it describes the improvement in performance since the implementation of Lean-Green manufacturing.

1= Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Item	Rating				
	1	2	3	4	5
We reduced the air emissions.					
We reduced the solid waste.					
We reduced the waste water.					
We decreased the consumption of hazardous/harmful/ toxic materials.					
We decreased the frequency of environmental accidents.					
We decreased the energy consumption.					
The quality of our products increased (defects reduction, products that meet customer needs, rate of customer complaints, number of warranty claims)					
We increased our flexibility (quick changes in product design, quick introduction of new products, quick changes in production volume, broad variety of products).					
We reduced the costs (low production costs, offer price as low or lower than our competitors, low overhead costs).					
Our delivery improved (quick delivery, on-time delivery, reliable delivery).					
We decrease the inventory levels.					
Our productivity increased.					
The production costs are predictable.					
We reduced the production lead time.					
The working conditions improved.					
The workplace safety improved.					
The employee health improved.					
The labour relations improved.					
The workers' morale improved.					
The work pressure decreased.					
The community health and safety improved.					
Our profits increased.					
The product development costs decreased.					
The energy costs decreased.					
The inventory costs decreased.					

	1	2	3	4	5
The rejection and reworking costs decreased.					
The raw material purchasing costs decreased.					
The waste treatment costs decreased.					
The fine for environmental accidents decreased.					

Section E: Barriers faced on the implementation of Lean-Green Manufacturing.

To what extent do you think each of the following items affects the ease of Lean-Green implementation in your organization.

1= Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Item	Rating				
	1	2	3	4	5
Lack of top management commitment.					
Lack of awareness/ information.					
Lack of organizational resources.					
Incompetent technology.					
Lack of training and education.					
Resistance to change.					
Fear of failure.					
Poor quality of human resources.					
Company culture.					
Financial constraints.					
High implementation costs.					
Weak legislation.					
Low enforcement of laws and corruption.					
Low public pressure.					
Uncertain future legislation.					
Lack of government support.					
Low customer demand.					
Uncertain benefits.					