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QUALITY PAPER

A hierarchical complementary Lean-Green model and its impact on operational performance of manufacturing organisations

Received 26 March 2022
Revised 26 November 2022
11 February 2023
18 April 2023
Accepted 31 May 2023

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Abstract

Purpose – This research aims to examine the complementary impact of Lean Manufacturing (LM) and Green Manufacturing (GM) on operational and environmental performance.

Design/methodology/approach – A survey was conducted in the Zimbabwean manufacturing industry. A total of 302 valid responses were obtained and analysed using partial least square structural equation modelling (PLS-SEM).

Findings – Both LM and GM impact environmental and operational performance; however, GM's effect on operational performance is indirect through environmental performance.

Research limitations/implications – This study only focusses on the Zimbabwean manufacturing industry, and the results may not readily apply to other developing countries.

Practical implications – The companies that have successfully implemented LM are able to implement GM more easily because of their complementary nature.

Social implications – The integration of LM and GM reduces most forms of waste, causing an improved environmental and operational performance. In addition, this will improve community relations and customer satisfaction.

Originality/value – This research investigates the complementary nature of LM and GM on how LM and GM impact organisational performance and whether a combined Lean-Green implementation leads to better organisational performance than when LM and GM are implemented individually. The research also examines whether being environmentally compliant leads to improved organisational performance, particularly in a developing country.

Keywords Green manufacturing, Lean manufacturing, Lean-Green, Environmental performance, Operational performance, Developing countries

Paper type Research paper

Funding: The research was funded by the University of Pretoria doctoral bursary request number 2553.

International Journal of Quality & Reliability Management
Vol. 41 No. 2, 2024
pp. 425-446
Emerald Publishing Limited
0265-671X
DOI 10.1108/IJQRM-03-2022-0115

1. Introduction

Whilst the rapid industrialisation of countries around the world has led to significant improvement in the economies, it also negatively impacted the environment (Ramos *et al.*, 2018). Furthermore, customers have increased their demand for improved quality products at lower cost and, more recently, reduction of the environmental effects of the production of goods and services (Garza-Reyes, 2015). Environmental issues are, therefore, considered as a competitive differentiation tool (Leme *et al.*, 2018). Also, the introduction of multicurrency in Zimbabwe induced instability in the economy (Maware and Adetunji, 2019a), and the gross domestic product (GDP) contracted by 8% between 2019 and 2020 (World Bank, 2021).

Such business environments pressure manufacturing organisations into implementing methodologies such as Lean Manufacturing (LM) and Green Manufacturing (GM) to help them address environmental issues (Ramos *et al.*, 2018), improve customer satisfaction and improve profitability. LM aims to reduce operational non-value-added activities such as excess inventory, waiting and defects (Ohno, 1988), whilst GM focusses on reducing negative environmental impacts like pollution and greenhouse gas emissions (Mohanty and Deshmukh, 1999).

The integration of LM and GM has gained popularity in both industry and academia due to their synergistic effect and the improvements they bring to organisations (Ramos *et al.*, 2018; Leme *et al.*, 2018). LM and GM may be complementary in three main areas: 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 where possible (Bhattacharya *et al.*, 2019). Also, they improve the company's 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). Integrating LM and GM can make manufacturing companies competitive and increase profits, which is the goal of most organisations (Fercoq *et al.*, 2016; Bhattacharya *et al.*, 2019; Thekkoote, 2022) and hence regarded as vital techniques that are deployed to improve financial and environmental performances (Kuo and Lin, 2020).

Whilst some aspects between Lean and Green may be contradictory, Green practices usually present opportunities to improve Lean performance, therefore, companies that adopt GM with LM may attain better results than those that don't (Fercoq *et al.*, 2016; Cherrafi *et al.*, 2018). King and Lenox (2001) emphasised that Lean can be considered Green as it acts as a catalyst to achieve improved GM results, and hence, researchers are exploring the synergistic effects between the two concepts to attain common benefits (Bhattacharya *et al.*, 2019). Thus, the purpose of this research is to investigate the impact of LM and GM on environmental and operational performance and compare the effects of their joint and individual implementations.

To address the objectives of this research, a survey was conducted in the Zimbabwean manufacturing industry. Most studies that have been conducted in Zimbabwe have also focussed on the individual implementation of LM and GM. For example, Goriwondo *et al.* (2013) and Maware and Adetunji (2019a) highlighted the impact of implementing LM on operational performance, whilst Kusena *et al.* (2014) realised the improvements in environmental performance as a result of GM implementation. Thus, creating questions on whether these organisations should simultaneously adopt LM and GM or not. Hence, this research provides answers to such gaps.

2. Literature review

2.1 Lean manufacturing

LM considers waste as the use of resources for any goal that does not create value for the customer (Pampanelli *et al.*, 2014). Fercoq *et al.* (2016) pointed out that traditionally LM focussed on seven types of waste, which are, defects, over-processing, excessive transportation, over-production, unnecessary inventory, unnecessary motion and waiting. They also noted that environmental waste could be considered the eighth waste. Clients are not keen to pay for these non-value-adding activities which impact quality, costs and performance (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 practices because it provides ways to improve performance (Kuo and Lin, 2020).

2.2 Lean manufacturing implementation in Zimbabwe

In Zimbabwe, various studies have been reported on the implementation of LM practices. Maware and Adetunji (2019a) reported an improvement in operational performance by applying Jidoka, stability and standardisation, just-in-time (JIT) and employee involvement. A study by Muchaendepi *et al.* (2019) on small and medium enterprises (SMEs) concluded that JIT is the most deployed strategy for inventory management and performance improvement. Madanhire and Mbohwa (2016) applied JIT and total quality management (TQM) in the aluminium foundry industry and realised improvement in operational performance. Ngwenya *et al.* (2016) examined the challenges faced in implementing TQM at a beverage company, some of which are economic challenges, resistance to change and inadequate funding.

2.3 Green manufacturing

GM is the application of environmental, economic and technological strategies to processes and products to improve the utilisation of resources and reduce the negative environmental impact over the entire life cycle of the products (Ramos *et al.*, 2018; Leong *et al.*, 2020). The fast rate of depletion of natural resources makes them scarce and expensive, making GM implementation a viable option; moreover, overuse of these resources leads to massive environmental damage (Fercoq *et al.*, 2016). Hines (2004) stated that the negative environmental impact is caused by greenhouse gases, excessive power usage, pollution, eutrophication, poor health and safety control, excessive water usage, excessive resource usage and rubbish. Thus, GM protects the environment by reducing toxic materials, using environmental-friendly processes and raw materials, designing for the environment, recycling and remanufacturing (Leme *et al.*, 2018).

2.4 Green manufacturing and its implementation in Zimbabwe

Evidence of GM implementation has been reported by Zimbabwe's manufacturing industry. Mbohwa (2002) stated that Zimbabwe could learn the development of GM technologies from Japanese companies in areas such as electronic environmental management. Mutubuki and Chirinda (2021) analysed how GM can be used in the food industry and suggested Green practices including recycle, reuse and reduce (3R) and green packaging. Masike and Chimbadzwa (2013) applied life cycle management (LCM), 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.

2.5 Integration of LM and GM in developing countries

Whilst implementing LM and GM separately by many manufacturing companies has helped to improve their operations, Baumer-cardoso *et al.* (2020) stated that LM and GM, when combined, can yield better results than alone. No case of LM and GM integration has been reported in Zimbabwe; however, other developing countries have made attempts. A study by Farias *et al.* (2019) in Brazil developed a framework to evaluate the impact of LM and GM on organisational performance. Huo *et al.* (2019) concluded that Lean-Green positively impacts sustainable development in China. Thanki *et al.* (2016) identified international organisation for standardisation (ISO) 14001 and total preventive maintenance (TPM) as the most influential Lean-Green practices in India. Dawood and Abdullah (2018) applied value stream mapping (VSM) and 3R in a cement-manufacturing company in Iraq, stating that these practices have a significant impact.

2.6 Research gap and problem statement

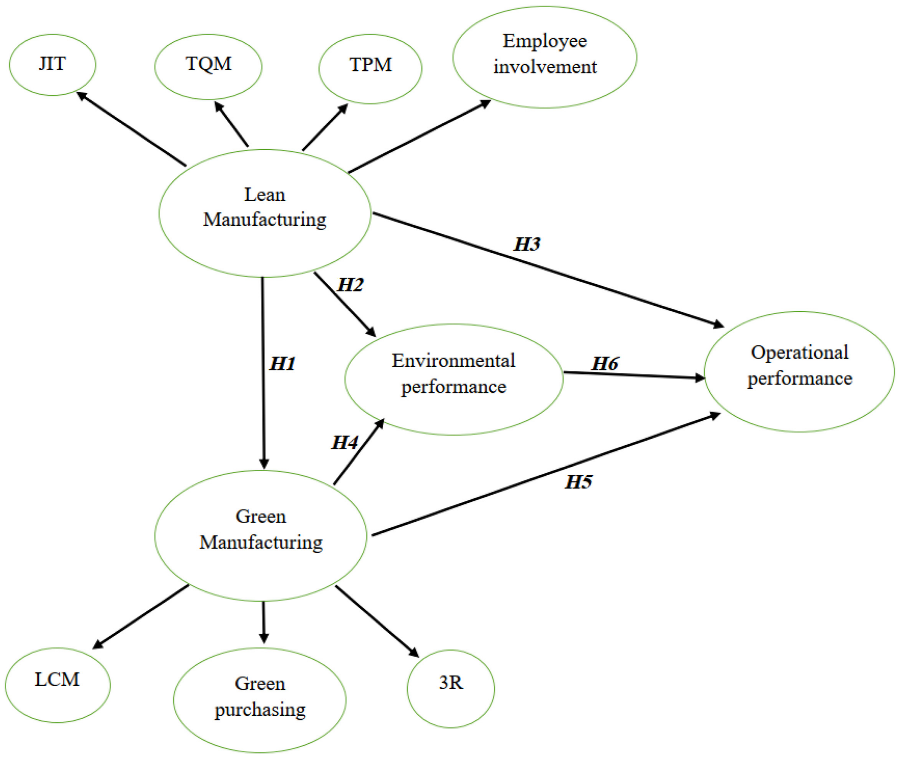
Although GM can be complementary to LM on environmental efficiency improvement Farias *et al.* (2019) acknowledged that there is little evidence of their successful integration, and the elements that allow for assessing Lean-Green on performance are still unknown. Garza-Reyes (2015) added that research focussing on the impact of Lean-Green practices on organisational performance is limited and inconclusive. Furthermore, many organisations have not benefited from Lean-Green due to a lack of a systematic implementation system, leading to haphazard implementations (Leong *et al.*, 2019).

It also seems like developing countries lag in implementing LM and GM, compared to developed countries (Panizzolo *et al.*, 2012; Fu *et al.*, 2017; Machingura and Zimwara, 2020). There is a lack of a standard measurement model to assess the impact of implementing these methodologies, and the companies are not sure which practices to adopt and the effect of such adoptions on their performance (Maware and Adetunji, 2019a). This makes management hesitant and sceptical about implementing these improvement philosophies (Maware and Adetunji, 2019b). Since both are based on continuous improvement, it is essential to assess the impact of their joint implementation on organisational performance (Farias *et al.*, 2019). Further research is, therefore, needed to address this gap in Lean-Green implementation.

This research investigates whether integrating LM and GM yields better results than implementing either of these methodologies alone. To the best of the authors' knowledge, the research by Green *et al.* (2018) is the only paper that applied structural equation modelling (SEM) to evaluate the impact of simultaneously implementing JIT, TQM and Green supply chain management (GSCM) on environmental performance. Our research extends this knowledge by using four bundles of LM, namely JIT, TPM, human resource management (HRM) and TQM instead of using JIT and TQM only. In addition, instead of using GSCM only, our research used LCM, 3R and Green purchasing. A higher-order model was used in this research, where the factors for LM and GM were separated so that LM factors only affect LM directly and GM factors only affect GM directly, and their mediation is studied separately. More importantly, this research examines the impact of LM and GM on operational performance in addition to the mediatory environmental performance impact. Also, Inman and Green (2018) investigated the impact of LM and GSCM on environmental and operational performance. Although a higher-order model was used, that research did not investigate the impact of simultaneously implementing LM and GM, thus, not addressing whether simultaneous implementation yields better results than individual implementations.

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 1, consisted of one endogenous variable, which is the operational performance and three exogenous variables, namely GM, LM and environmental performance. LM and GM are second-order latent variables, whereas 3R, LCM and Green purchasing are first-order latent variables for GM, whilst JIT, TQM, TPM



Source(s): Author's own creation

Figure 1.
Hierarchical Lean-Green structural model

and employee involvement are the first-order latent variables for LM. Several previous studies 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); therefore, these practices were adopted for this study. Additionally, Khan *et al.* (2019) applied Green purchasing whilst Dawood and Abdullah (2017) used 3R and realised an improvement in organisational performance, whereas Dües *et al.* (2013) mentioned that LCM is the principal GM tool. As a result, this motivated the authors to adopt all these LM and GM practices and examine the complementary impact of LM and GM implementations.

Elimination of wastes like defects, over-processing and overproduction are critical goals of LM, which have been reported to support the GM philosophy as they consequently result in efficient use of resources such as water, energy and raw materials, which are important aims of GM. Thus, LM outlines a way for the improved utilisation of resources (Pampanelli *et al.*, 2014), and this indirectly helps in the achievement of GM objectives. Lean practices are, therefore, treated as Green because their objectives, in this sense, are in line with saving resources (Fercoq *et al.*, 2016). The study by Thekkoote (2022) in South Africa's SMEs also found that LM has a positive relationship with GM. Kuo and Lin's (2020) study demonstrated that LM positively influences Green operations. It can, therefore, be hypothesised as follows:

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 may also reduce negative environmental impact.

Several articles have indicated that LM has a positive impact on environmental performance. 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. 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 as follows:

H2. LM is positively related to environmental performance.

Manufacturing companies are implementing Lean practices such as TQM, JIT and TPM to improve quality and productivity. 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 the implementation of LM made 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 as follows:

H3. LM is positively related to operational performance.

The GM philosophy has been well recognised for reducing negative ecological issues (Garza-Reyes, 2015). It aims to improve, control and monitor pollution levels, minimise the impact of manufacturing processes on the environment as well as provide for efficient use of resources (Farias *et al.*, 2019). It examines environmental impact related to the unnecessary use of energy or water, eutrophication and the greenhouse effect (Baumer-cardoso *et al.*, 2020). GM advocates for eliminating 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.*, 2020). It can, therefore, be hypothesised as follows:

H4. GM is positively related to environmental performance.

GM's objective is to reduce pollution levels and provide efficient resource usage (Qureshi *et al.*, 2015). If water, energy, raw materials and other resources can be used efficiently, costs can also 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 the implementation of GM improves operational performance. Green practices were found to impact Pakistani manufacturing organisational performance (Khan *et al.*, 2019). Thus, it can be hypothesised as follows:

H5. GM is positively related 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. The study done on Chinese manufacturing companies concluded that the implementation of environmental policies positively impacts company performance (Zhang and Du, 2020). It was also noted that environmental collaboration plays a significant part on organisational performance (Chin *et al.*, 2015). According to research in Thailand's food industry, environmental performance improves operational performance in this industry (Pipatprapa *et al.* 2016). Thus, it can be hypothesised as follows:

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, currently, researchers have noted that when LM and GM are combined, they tend to 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 these practices are combined, they have a larger impact than when implemented individually. Hence, it can be hypothesised as follows:

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 on environmental and operational performance. The model is illustrated in Figure 1.

4. Methodology

4.1 Questionnaire development

A self-administered questionnaire was developed to assess the impact of Lean-Green implementation on the environmental and operational performance of manufacturing companies. To enhance the validity of the questionnaire, it is usually recommended to adopt questions from the literature (Murillo-Luna *et al.*, 2011; Huo *et al.*, 2019; Shashi *et al.*, 2019). The questions for this research 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 four sections. Section A focussed on the general information about the company. Section B outlined the level of LM adoption by manufacturing companies. Section C covered the level of GM adoption. Section D focussed on the impact of implementing selected Lean-Green practices on environmental and operational performance. 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. 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 (see Appendix).

4.2 Data collection

Data was collected from manufacturing companies across Zimbabwe. Currently, they are 430 manufacturing companies registered with the Confederation of Zimbabwe Industries (CZI). A total of 782 questionnaires were sent to respondents within these 430 companies. The authors were targeting more than 1 response from each company and hence decided to send 2 to 3 questionnaires to each company so that in case of individual biases, the responses counterbalance each other as recommended by Maware and Adetunji (2019b). 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 and safety, health, environment and quality (SHEQ) departments were chosen because these are the areas that are responsible for the operational and environmental performance measures (Jabbour *et al.*, 2013). The responses were kept anonymous with a high level of confidentiality (Murillo-Luna *et al.*, 2011). Initially, 313 questionnaires were returned as some personnel did not respond. The questionnaires were screened, and 302 valid and useable responses were obtained. A total of 11 questionnaires were incomplete and were discarded. This gave a 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). Also, based on the 10-times rule specified by Hair *et al.* (2017), the minimum sample size is 120; therefore, we considered the sample to be adequate as we were well above the minimum limit.

4.3 Non-response bias

Non-response bias was determined using the early and late responses method described by Armstrong and Overton (1977). A total of 5 items were randomly chosen from the questionnaires to compare the first 20 and last 20 responses. The results of the t-tests showed no significant difference at the 0.05 significance level, implying a lack of non-response bias that could have affected the results (Chavez *et al.*, 2022).

5. Data analysis and results

Data analysis was done using the SmartPLS 3 and Statistical Package for Social Sciences (SPSS) version 26. SPSS was deployed for the descriptive statistics and Exploratory Factor Analysis (EFA), whilst SmartPLS was used for SEM 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 (Inman and Green, 2018).

5.1 Profile of participants

The distribution of the companies is indicated in Table 1. The highest responses per sector were 89 from the food and beverage sector and 33 from the plastic and rubber sector.

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).

5.2 Assessment of the measurement scale

The 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 an 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

Type of industry	Number of respondents	%
Food and beverage	89	29.5
Chemical and petrochemical	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
Fertiliser	7	2.3
Textile	15	5.0
Leather	6	2.0
Paper	10	3.3
Ceramic	5	1.7
Steel working	13	4.3
Tile and brick	11	3.6
Automotive	5	1.7
Battery	7	2.3
Foundry	8	2.6

Source(s): Author's own work

Table 1. Type of industry

values > 0.5 indicate a strong convergent validity (Hair *et al.*, 2017). The AVE values obtained in this research were > 0.5. 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 2, all the outer loadings were > 0.5 (see Table 2).

Discriminant validity was assessed using the Heterotrait-Monotrait ratio (HTMT) ratio. As shown in Table 3, all the constructs exhibited discriminant validity as the HTMT values were all < 0.85 (Hair *et al.*, 2017). Therefore, the scale denotes enough reliability and validity; thus, the variables can be used for further research on hypotheses evaluation.

5.3 Structural model assessment

The variance inflation factor (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 Cohen (1988), R^2 values greater than 0.26 are substantial, 0.13 are moderate and 0.02 are weak. Hair *et al.* (2017) also mentioned that the R^2 values depend on how complex the model is; therefore, R^2 value of 0.20 can be considered high. 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%, LCM 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 highlights that most of the relationships have a large effect. The relationship between GM and operational performance was denoted by a small effect whilst LM to environmental performance relationship had a medium effect. The Stone–Geisser's Q^2 value indicates the predictive relevance of the model (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 as shown in Table 5.

The significance of the paths was determined through the bootstrapping method using 5,000 subsamples (Godinho Filho *et al.*, 2016; Ghobakhloo *et al.*, 2018). Most of the proposed

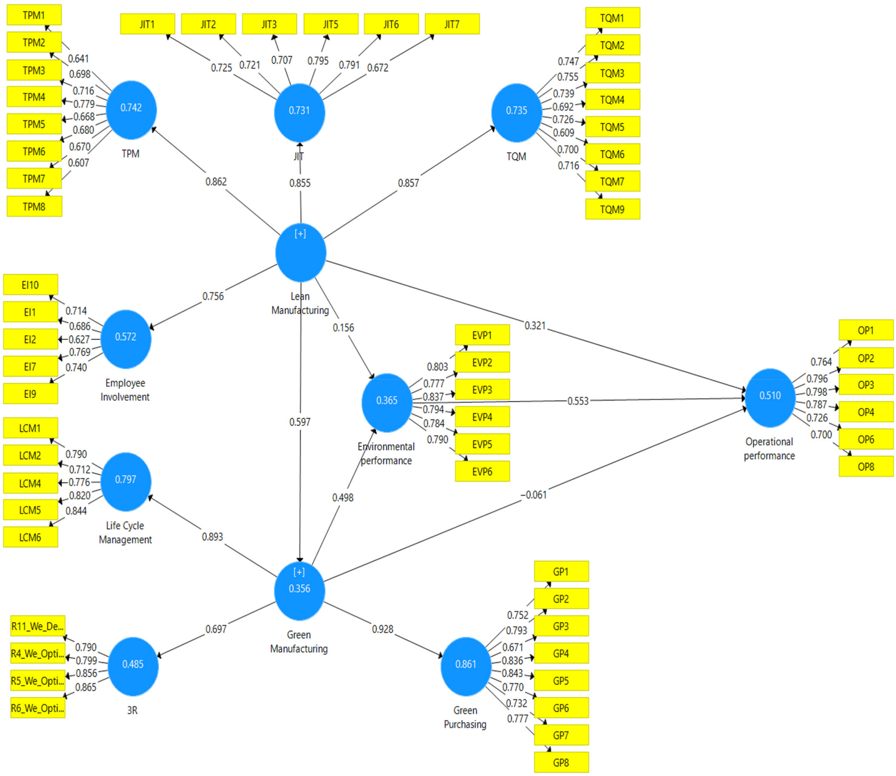


Figure 2.
Results for the structural model

Source(s): Author's own work

Table 2.
Measurement reliability and validity

	Cronbach's alpha	Composite reliability	AVE
3R	0.847	0.897	0.686
Employee Involvement	0.751	0.834	0.502
Environmental performance	0.886	0.913	0.636
Green Manufacturing	0.926	0.936	0.501
Green Purchasing	0.903	0.922	0.598
JIT	0.83	0.876	0.543
Lean Manufacturing_	0.928	0.935	0.509
Life Cycle Management	0.848	0.892	0.623
Operational performance	0.856	0.893	0.582
TPM	0.837	0.875	0.568
TQM	0.86	0.891	0.507

Source(s): Author's own work

relationships are statistically valid as they have *t*-values above 1.96 and *p*-values lower than 0.05 at a 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 as shown in Table 6.

	3R	EI	EVP	GM	GP	JIT	LCM	LM	OP	TPM
EI	0.552									
EVP	0.711	0.426								
GM	0.788	0.517	0.652							
GP	0.519	0.404	0.505	0.763						
JIT	0.525	0.668	0.482	0.66	0.588					
LCM	0.578	0.462	0.578	0.540	0.662	0.623				
LM	0.519	0.317	0.496	0.639	0.575	0.556	0.587			
OP	0.515	0.541	0.758	0.515	0.42	0.568	0.46	0.596		
TPM	0.445	0.81	0.399	0.508	0.455	0.772	0.444	0.499	0.475	
TQM	0.378	0.634	0.459	0.586	0.569	0.763	0.553	0.351	0.548	0.709

Note(s): EI = employee involvement, EP = environmental performance, GP = Green purchasing and OP = operational performance
Source(s): Author's own work

Table 3.
HTMT values

	3R	EI	EP	GM	GP	JIT	LCM	OP	TPM	TQM
EP								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

Source(s): Author's own work

Table 4.
The f^2 values

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

Source(s): Author's own work

Table 5.
The Stone–Geisser's Q^2 values

	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

Note(s): *The direct relation between GM and operational performance is not supported; the impact is indirect through environmental performance
Source(s): Author's own work

Table 6.
t-statistics and *p*-values and decision on the hypotheses

To determine if the combined effect is stronger than singular impacts, the authors adopted the stepwise regression method, using LM first and GM second, and noted the increments in adjusted R^2 (Green *et al.*, 2018). Since GM is a newer 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, whilst GM focusses on reducing environmental impact, organisations are likely to adopt LM before GM as most organisations are likely more interested in improving their operational performance ahead of environmental compliance.

LM and GM practices were stepwise regressed against environmental and operational performance. When LM was used as the first antecedent to environmental performance, the adjusted R^2 found was 0.198. When GM was added as the second antecedent, the adjusted R^2 increased by 0.16, from 0.198 to 0.358. Next, LM was also used as the first antecedent to operational performance and the adjusted R^2 value of 0.282 was obtained. Again, GM was added as the second antecedent to operational performance and a 0.054 increase was noticed, yielding the adjusted R^2 of 0.336. Finally, when environmental performance was added as the third antecedent to operational performance, the adjusted R^2 increased to 0.502. The calculated t-values were greater than 1.96, indicating that these increments are significant at 0.05 level. Thus, the complementary relationship between LM and GM results in better environmental and operational performance, compared to individual practices. Therefore, hypotheses H7 and H8 are supported. This agrees with Leong *et al.* (2019) and Leong *et al.* (2020) who stated that integration of LM and GM practices yields improved environmental and operational performance.

To investigate if there is some form of heterogeneity in the pattern across industries based on possible levels of pollution, further analysis was done by clustering companies into two categories depending on their position in the supply chain. Since Zimbabwe as a country does not have manufacturing companies in sectors like oil exploration, refinery or steel manufacturing, industry clusters were created based on the type of supply chain processes involved and the level of integration inherent in the manufacturing processes. Category 1 consists of companies that work across an entire chain and convert raw materials to finished products. These sectors include food and beverage, agrochemical, tile and brick, wood and furniture, leather, paper and fertiliser. Category 2 is made up of companies that import semi-finished products and process them into finished products. These include chemical and petrochemical, plastic and rubber, pharmaceutical, electronics and electrical, textile, ceramic, steel working, automotive, battery and foundry. It is believed that the processes of these two categories should suffice to understand different GM footprints based on the manufacturing processes, and therefore, they might produce different results (see Table 7).

The results led to similar conclusions and indicated that Lean-Green yielded identical improvements in both categories. Lean-Green makes organisations improve their environmental and operational performance. LM has a positive relationship with operational and environmental performance, whilst GM has a positive relationship with environmental performance. Furthermore, GM has no positive relationship with operational performance, but the relationship is indirect through environmental performance.

6. Discussion of the results

This study investigated the impact of adopting LM and GM on the environmental and operational performance of manufacturing companies in Zimbabwe. Lean-Green has

	Category 1				Category 2			
	Path weight	*t*-statistics	*p*-values	Decision	Path weight	*t* -tatistics	*p*-values	Decision
EP → OP	0.390	2.105	0.036	Supported	0.546	4.933	0.000	Supported
GM → EP	0.265	1.987	0.047	Supported	0.425	3.919	0.000	Supported
GM → OP	0.073	0.312	0.755	Not supported	−0.123	1.097	0.273	Not supported
LM → EP	0.530	2.964	0.005	Supported	0.178	1.981	0.018	Supported
LM → GM	0.756	8.688	0.000	Supported	0.650	10.776	0.000	Supported
LM → OP	0.466	2.372	0.010	Supported	0.273	2.465	0.014	Supported

Source(s): Author's own work

Table 7. Comparison of category 1 and category 2

emerged as a new and essential manufacturing philosophy that can be adopted by manufacturing companies to achieve competitive advantage (Basha *et al.*, 2020; Siegel *et al.*, 2022). 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). Researchers have recently started investigating the relationship between LM and GM and how they mutually affect organisational performance. Nevertheless, there are still many opportunities for research in this area, especially in developing countries where such work seems to be lagging.

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 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) and Lara *et al.* (2022). In contrast, the research by Khalfallah and Lakhal (2020) highlighted that TQM, JIT and TPM do not have a positive influence on operational performance.

GM was found to have a positive relationship with environmental performance. This agrees with the study conducted in the Indonesian manufacturing and logistics industry (Firmansyah and Maemunah, 2021). The results failed to support the hypothesis that GM has a direct positive relationship with operational performance; nevertheless, it depicted that GM indirectly impacts operational performance through environmental performance. GM was found to be positively related to environmental performance, whilst environmental performance was found to have a positive relationship with operational performance. Thus, although there is no positive relationship between GM and operational performance, an indirect relationship exists through environmental performance. According to Figure 2, the direct path weight between GM and operational performance is −0.061, whilst the indirect effect through environmental performance is 5 times greater, thus 0.275 (0.498 times 0.553). The primary aim of GM is to reduce environmental impact regardless of the cost and lead time implications. In other words, the finding here is that improvement in operational performance is not directly achieved through GM implementation but from the consequences of improvements in environmental performance attained by implementing GM. This is consistent with the USA firms' survey (Inman and Green, 2018).

This finding is particularly important as the model by Green *et al.* (2018) that has previously studied the integrated Lean-Green impact on performance did not separate the direct impact of the lower level factors of Lean on Green and those lower level factors of Green on Lean, but rather connected all the lower level factors to each of these two factors. Consequently, this model might have lumped together both the direct and indirect effects of Lean and Green implementations on the performances measured. In addition, separating environmental effects from operational effects makes it possible to observe the role that environmental improvement plays in the integrated Lean-Green impact.

Therefore, those organisations integrating LM and GM, without paying attention to their environmental performance, may fail to realise the full benefits of the complementary relationship between LM and GM. Also, LM without GM significantly improved operational performance, but its impact on environmental performance is slightly lower. The indirect impact of LM on environmental performance through GM is greater than the direct impact, and this is another interesting finding. Thus, integrating LM and GM causes a significant improvement in environmental performance and further enhances operational performance. Furthermore, when the manufacturing companies were clustered into two different categories in the context of Zimbabwe, the results showed that Lean-Green positively impacts environmental and operational performance in both categories.

More importantly, the integration of LM and GM showed a greater impact, compared to the implementation of GM and LM separately. This agrees with an earlier study which found that combining LM and GM practices yields better results than implementing one of the methodologies (Green *et al.*, 2018). This was also confirmed by Dües *et al.* (2013) who noted that LM acts as a catalyst for attaining better Green improvements. Lean practices aim to reduce non-value-adding operations, thereby increasing efficiency whilst GM aims to improve environmental performance (Firmansyah and Maemunah, 2021).

The results from this study also agree with other studies conducted in Zimbabwe. For instance, Maware and Adetunji (2019a) conducted a survey and reported improved operational performance through the implementation of LM, whilst in the pharmaceutical industry Goriwondo *et al.* (2013) adopted LM and also highlighted improved operational performance. In addition, the study by Kusena *et al.* (2014) indicated improvements in environmental performance through GM implementation in the cement industry.

In Zimbabwe, it seems no study has been conducted to evaluate the combined impact of Lean-Green on environmental and operational performance. Thus, this study sheds more light on the Zimbabwean manufacturing industry and encourages organisations to simultaneously implement LM and GM. Considering the economic challenges faced in Zimbabwe and also the increased environmental demands by regulators, combining LM and GM assists these organisations to meet both operational and environmental objectives.

7. Conclusion, implications, limitations and future research opportunities

7.1 Conclusion

This research examined the impact of implementing Lean-Green practices on organisational performance. The research objective was to explore the actual nature of the relationship between Lean and Green improvements and understand which paths in the relationship lead to which performance improvements, either directly or indirectly. It also seeks to shed more light on the impact of Lean-Green in the context of a developing country and assist those organisations that worry about adopting such methodologies. Particular attention was given to environmental and operational performance. It was discovered that Lean-Green has an impact on operational and environmental performance. Furthermore, 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. Furthermore, organisations intending to achieve operational benefits from their Green implementation need to pay particular attention to the role of environmental performance, as this is how the operational performance is enhanced. This makes sense since Green prescripts may demand large lot sizes, whilst Lean prescripts demand smaller lot sizes, which are generally contradictory, but the aggregate effect may produce better results than the sum of the individual parts.

7.2 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 also on 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 and Green customers as all their requirements will be fulfilled, thus increasing competitiveness.

Most studies that have been done focussed 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. Hence, managers are now aware that when LM and GM are implemented simultaneously, they yield better results than their individual implementation. 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.

7.3 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, policymakers, communities and customers demanding organisations to adopt environmentally friendly and sustainable manufacturing. This research has 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.

7.4 Study limitations and future opportunities

The research was conducted through a survey of the manufacturing companies in Zimbabwe only. Thus, the results are generalised as it focusses on many sectors of the manufacturing industry. 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, but may provide the norm for benchmark purposes. Thus, similar research can be conducted in other developing countries and results compared with those obtained in this study. Lean-Green is not limited to the manufacturing industry only; hence, it can be expanded to other sectors such as construction. Even though the research dwells on environmental sustainability, it may be imperative to extend it to different dimensions of sustainability; thus, the social construct may be further isolated in subsequent studies.

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Appendix
Measurement scale

Employee involvement

(1) Our workers undergo cross-functional training;

(2) The suggestions of the team members are considered before making decisions;

(3) At our firm, we have an expansion of autonomy and responsibility;

(4) In our company, the management takes all improvement suggestions seriously and

(5) The employees are encouraged to work together to achieve common goals.

TPM

(1) Our operators are trained to maintain their own machines;

(2) Our equipment is always in a high state of readiness;

(3) We keep the records of routine maintenance;

(4) We maintain all our equipment regularly;

(5) The equipment maintenance records are shared with all the shop floor employees;

(6) Our operators understand the cause and effect of equipment deterioration;

(7) Our operators inspect and monitor the performance of their own equipment and

(8) Our operators can detect and treat abnormal operating conditions of their equipment.

JIT

(1) Our customers receive just-in-time deliveries from us;
(2) Our suppliers deliver to us on a just-in-time basis;
(3) Our company involves all the key suppliers in the process;
(4) The daily production schedule is met every day;
(5) The daily production schedule is completed on time and
(6) The layout of our shop floor facilitates low inventories and fast throughput.

TQM

(1) Our equipment or processes are under statistical quality control;
(2) We use statistical techniques to reduce variance;
(3) Control charts are used to determine whether the manufacturing processes are in control;
(4) The processes in the plant are designed to be "foolproof";
(5) The process ensures that all parts, materials, information and resources meet the specifications before use;
(6) Our customers give us feedback on our quality and delivery performance;
(7) We undertake programs for quality improvement and control and
(8) Quality problems can be traced to their source and solved without reworking too many units.

3R

(1) We optimise the processes to reduce water use;
(2) We optimise the processes to reduce air emissions;
(3) We optimise the processes to reduce energy use and
(4) We design the products for reduced consumption of energy.

LCM

(1) We systematically consider customer feedback for eco-design;
(2) Our company considers its discharges as a wealth;
(3) We recover the company's end-of-life products;
(4) We consider the impact of products in their entire lifetime and
(5) We monitor the environmental impact of the products at all stages.

GP

(1) We coordinate with the suppliers for environmental objectives;
(2) We perform the environmental audit for suppliers' internal management;
(3) Our suppliers are ISO14000 certified;

(4) We choose our suppliers by environmental criteria;

(5) We urge/pressure our supplier(s) to take environmental actions;

(6) We provide the design specification to suppliers that include environmental requirements for purchased items;

(7) Our products are eco-labelled and

(8) Our firm has an environmental purchasing policy in practice.

Environmental performance

(1) We reduced the air emissions;

(2) We reduced the solid waste;

(3) We reduced the waste water;

(4) We decreased the consumption of hazardous/harmful/toxic materials;

(5) We decreased the frequency of environmental accidents and

(6) We decreased the energy consumption.

Operational performance

(1) The quality of our products increased (defects reduction, products that meet customer needs, rate of customer complaints and number of warranty claims);

(2) We increased our flexibility (quick changes in product design, quick introduction of new products, quick changes in production volume and broad variety of products);

(3) We reduced the costs (low production costs, offer price as low or lower than our competitors and low overhead costs);

(4) Our delivery improved (quick delivery, on-time delivery and reliable delivery);

(5) Our productivity increased and

(6) We reduced the production lead time.

Source(s): Authors' own work

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