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A Synergetic Framework for Green and Lean Manufacturing Practices in SMEs: Saudi Arabia Perspective

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Abstract: Manufacturers are urged to improve their sustainability performance, in terms of keeping the balance among economic, environmental, and social performances. Nevertheless, top managers and company leaders tend to complain that it is not possible to implement greener solutions without large investments. In this context, the well-known lean manufacturing approach, mainly focused on waste reduction, has come to be viewed with a renewed interest towards improving not only economic but also environmental and social aspects. Unfortunately, while there is no doubt that lean manufacturing increases productivity, efficiency, quality, and customers' satisfaction by reducing wastes, there is a lack of research about the benefits of lean practices in relation to green manufacturing. The aim of the present work is to investigate the level of integration of green and lean manufacturing approaches, focussing specifically on the context of Saudi Arabia. As a result, a novel theoretical framework capable of combining the lean and green approaches within a synergetic environment, enhancing the former and mitigating the latter, is proposed. A survey was put together for assessing a number of hypotheses and validating the proposed framework. Qualitative analysis based on a survey conducted in different SME manufacturing companies in Saudi Arabia is presented. The statistical analysis of the collected data shows a clear trend that in Saudi Arabia, companies are starting to have a positive view about the integration of lean and green approaches implementation. The results highlighted higher maturity among the respondents with regard to the lean implementation, focussing on operational improvements. The improvements that can be attained with regard to environmental performance are coming next, and the framework proposed can help increase awareness among Saudi manufacturing SMEs.

Keywords: lean manufacturing; green manufacturing; lean-green manufacturing; sustainability

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1. Introduction

Climate change is a fact, placing organizations' activities and operations under scrutiny. As a result of this, manufacturing practice impacts on the environment are monitored and attempts are recorded for reducing and even eliminating them. This has highlighted environmental responsibility cruciality, compelling companies to consider environmental and social aspects besides economic ones. In this context, companies are urged to adopt green initiatives [1] such as decreasing hazardous emissions, eliminating the consumption of wasteful resources, and recycling [2]. Under current circumstances, where several countries are facing serious economic difficulties, the raw materials and the transportation costs are rising, and the credit market is getting tougher, the need for an eco-oriented approach focused on optimising the use of the available resources, from the environmental as well as economic points of view, seems to increase day after day.

For several years, the main motivation for manufacturers has been to satisfy or create needs, while keeping competitiveness in terms of product quality, time to market and innovation. Nevertheless, in recent years, it has been highlighted that manufacturing

philosophies based on customer demand, together with the improved living standards, have led to a growing product demand, fulfilled by a huge amount of produced goods, ending up in an increasing generation of pollution and wastes. In this context, companies are compelled to move towards more sustainable manufacturing practices, simultaneously keeping the balance among economic, environmental and social performances [3]. Nevertheless, to actually implement green manufacturing is not always straightforward. In particular, although becoming greener would result in several benefits, reducing not only the environmental risks, but also the health risks, having safer, healthier and cleaner companies, improving product quality and even the companies' public image [4], many industries' senior leaders consider environmental regulations as a burden for production and a factor reducing their potential in further increasing their profits.

Some promising results have been obtained either by adapting lean practices to address green objectives [5–9], or by improving green practices in terms of economic efficiency [10,11]. However, researchers agree that neither lean nor green practices can fulfil the current sustainability requirements when implemented independently [12,13]. To comply with the environmental regulations, as well as to remain competitive, companies need to be creative and propose new strategies to move towards a greener industry while keeping it profitable [14,15].

In this line, several manufacturers that were already implementing lean manufacturing have realised that becoming "green lean" would be a natural progression, allowing them to create cleaner production methods based on lean principles so that the environmental aspects of the processes could be improved, while the benefits (particularly the economic ones) that they have already achieved by the already applied lean practices could be sustained [15]. Unfortunately, to combine both lean and green manufacturing approaches into a single one is a very complex and challenging task [16,17]. In addition, there is a lack in the literature of suitable integration and combination strategies as well as of successful empirical evidence of their practical implementation [13]. A thorough literature review was presented by the authors in 2020 [18], highlighting the growing interest from academia in the combination of green and lean. In the context of the present paper, this literature review will be complemented with relative works presented after the initial literature review paper was published.

One of the major findings of the literature review analysis back in 2020 was that although the green lean approach seems to be promising, the conflicting results found in the literature make it necessary to further investigate the actual possibilities of their integration, the potential of the combined approach, and its influence in different aspects of the system's performance, such as economic, environmental and social ones. In addition, although both practices are related with the concept of sustainability, predictions with regard to the way they are related are difficult to find in the literature. Finally, it was highlighted that no study has been presented in the context of Middle East countries, and specifically Saudi Arabia.

In this context, the main aim of the present research is to investigate the actual lean-green combined approach implementation in order to provide researchers and practitioners creative tools towards achieving the currently required levels of sustainability, keeping the balance among economic, environmental and social performances. The paper is in the context of Saudi Arabia SME manufacturing organizations.

2. Literature Review

Lean manufacturing provides organizations with the tools to improve their competitiveness based on increasing value to customers, in terms of productivity, efficiency, quality and costumer satisfaction, by reducing resource consumption via waste elimination [19]. With the expansion of globalized markets, the manufacturing industry is booming with opportunities across the world. This global market also poses challenges to the manufacturing industry such as monetary fluctuation factor, political influence, economic stability, technological innovation, regulatory restructuring, and environmental pressure

that have been constantly altering the competitive landscape [20]. Of all the challenges mentioned above, the manufacturing industry today faces two core challenges—pressure of supply–demand and climate change around the globe. There is a need to strike a good balance between operation and environmental performance [21]. Increasing concerns from the environment, a fast-changing global business arena and pressure from the external government bodies are now nudging manufacturing organizations to proactively work on creating cleaner processes and minimize the impact on the environment [13]. Lean manufacturing focuses on creating value for the customer, which means that all activities in the production system and supply chain that do not add value should be eliminated, or at least reduced [22]. This translates into elimination of various forms of waste, including over-production, waiting, unnecessary transport, overprocessing, excess inventory, unnecessary movement, defects and unused employee creativity [23]. Green practices are focused on reducing hazardous emissions, removing the consumption of wasteful resources, recycling, and minimizing health risks throughout the entire manufacturing process, by minimizing the environmental footprint during the whole product life cycle [24]. Green manufacturing takes lean manufacturing a step forward in improvement of environmental efficiency of an organization [25]. The impact of constant focus on waste reduction, efficient use of resources and evolving customer needs has created a case for manufacturing organizations to adopt lean and green processes [14,22,26,27]. The concept of combined lean and green efforts called "lean green" give an opportunity to address a triple bottom line, which covers the economic, environmental and social dimensions of the manufacturing system [28]. There are a variety of schools of thought in this regard. Some studies suggest that lean drives green, some suggest green drives lean, while others believe that they should be applied simultaneously [29]. The literature reports that there are similar capabilities between lean and green besides some obvious differences [22]. Lean strategy reduces the marginal cost of green policies through reduction of implementation cost and provides additional inputs needed for reduced environmental impact [30]. If applied simultaneously, organizations can enhance both their financial and environmental efficiency. Although some promising results have been reported in the literature by adapting lean practices to address greener objectives, there is a need to further simplify the complex relationship between the two concepts [17,31,32]. This can be achieved by bridging the gap, causing multiple barriers to be jointly implemented. These barriers are the lack of environmental knowledge, lack of top management commitment, resistance to change, financial restrictions, insufficient government support, technological constraints, and lack of dedicated supplier base [33]. Marco-Ferreira et al. [34], in their review study, presented an overview of the conceptual frameworks related to the lean-green practices, paradigms, and prospects. The results demonstrated that positive approximation of the lean-green union influences other environmental performance variables. The lean manufacturing tools/methodologies/concepts that enable the lean-green approach are kanban, cellular manufacturing, value stream mapping, single minute exchange of dies, standardized work, total productive maintenance, kaizen, 5S, lean training, six sigma and lean line design. The green manufacturing tools/concepts/tools that enable the lean-green approach are environmental management system, green design, life cycle assessment, 3R (reduce, recycle and reuse), environmental emission control, pollution prevention, green procurement and waste treatment [35]. Lean management alone does not have a significant positive impact on environmental performance as it does on operational performance unless the organization falls into a high maturity group. Green manufacturing, however, has a significant positive impact on both environmental and operational performance regardless of the organization's maturity level [36]. Further, there is evidence that indicates that implementation of an integrated lean-green manufacturing system has motivated operations managers and decision makers to consciously consider its implementation in their manufacturing organizations [37]. To fulfil the current sustainability requirements, the combination of lean and green practices must be used so that their strengths can be enhanced and their weaknesses can be mitigated. Further research needs to be conducted towards evaluating the actual possibility of integrating the lean and green approaches, the potential of the combined approach and its influence on sustainable

aspects in terms of economic, environmental and social performances. However, based on the systematic literature review, the analysis showed that promising results have been achieved only by qualitative studies carried out within the context of different manufacturing environments, such as the construction, food and automotive industries. Many of these studies are surveys, and there is a lack of quantitative studies in the literature [18].

3. Research Methodology and Approach

To actually combine lean and green approaches is a complex and challenging task [17]. The conducted research is aimed at proposing a new framework capable of combining lean, green and lean-green approaches in a synergetic and efficient way in order to achieve a superior sustainable performance, simultaneously keeping the balance among economic, environmental and social performances. Then, the main aim of the presented research is to identify the most efficient strategy for combining lean, green and lean-green approaches towards achieving simultaneous improvements in economic, environmental and social performances.

For achieving this aim, a number of research questions have been set that are listed hereafter:

- What are the current trends in lean and green manufacturing and their link with the different aspects of sustainability?
- To what extent are these practices (lean and green) actually implemented in a real manufacturing scenario? Which benefits have been reported? Which barriers have practitioners encountered?
- What are the currently available and implemented lean-green strategies and their link with sustainability?
- What are the best strategies or theories to combine different manufacturing approaches?

The conducted research and, thereby, the selected methodology to conduct it is intended to answer each one of the above-listed questions towards finally achieving the main research aim. According to Mackenzie and Knipe [38], there is a plethora of literature proposing different methods for addressing the research design, being sometimes confusing to select the best suited one. In such a context, it is crucial to deeply understand the research problem as well as the main aims of the conducted research in order to be able to select the most suitable research methodology to address it.

For the needs of this research, a hybrid quantitative and qualitative approach was selected to conduct the research within the onion framework. In particular, quantitative research is focused on systematically studying a phenomenon by gathering quantifiable data that can be analysed resorting to statistical, mathematical or computational techniques [39]. The conducted research is based on a survey including both close-ended (Likert scale) questions as well as open-ended (textual) questions. On one hand, using close-ended (Likert scale) questions allows one to collect quantifiable data that can be quantitatively analysed resorting to mathematical and statistic methods in order to achieve statistically significant results, in the sense of being unbiased and capable of reflecting the characteristics of the whole sampled population.

In order to ensure that the data collected via the conducted survey are statistical significant, as well as to ensure that the obtained results from the corresponding data analyses are acceptable, valid, meaningful and, even more important, generalizable, it is mandatory to validate the performed survey [38]. In this line, the questions included in the questionnaires used for collecting the data are validated for assessing their dependability. This validation process includes, on one hand, the pre-process of the collected data from the questionnaires in order to properly prepare it to be analysed and, on the other hand, the data analysis based on carefully selected statistical methods so that the reliability of the results can be ensured [40]. In order to do so, the six steps suggested by Collingridge [40] were followed: face validity; pilot test; clean collected data; use principal components analysis (PCA); check internal consistency; revise the survey (Figure 1).

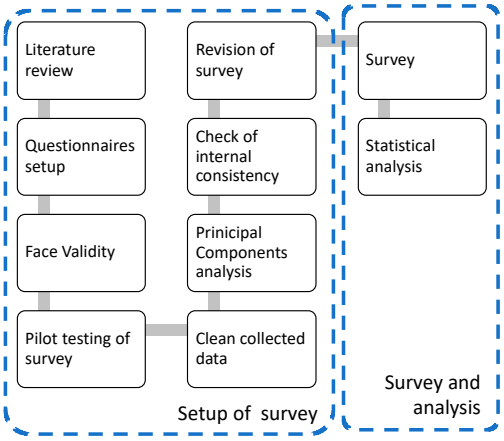

Figure 1. Methodology adopted for the present study.

4. Synergetic Framework for Green-Lean Practices: An Integrated Approach

The first step for the development of a framework that will allow for the integration of lean and green practices for improving sustainability performance of an organization is based in the profound understanding of how lean and green approaches are interrelated. More specifically, a set of hypotheses is developed regarding how lean, green and lean-green approaches can contribute towards improving sustainability in terms of economic, environmental and social performances. These hypotheses and their interactions are then modelled and combined into the theoretical framework integrating lean, green and lean-green approaches.

The proposed conceptual framework is shown in Figure 2. It suggests modelling the contribution and importance of lean, green and lean-green practices to the different considered aspects of sustainability, viz., operational, environmental and social, by a set of hypotheses. The confirmation or rejection of these hypotheses will lead to a combination strategy that can have multiplying effects in sustainability improvements. In this line, in order to estimate to what extent lean and green aims are reached by lean and green practices, Hypotheses (H1a–c) and (H2a–c) model the contributions of lean and green practices to the operational, social and environmental performances, respectively. Once these contributions have properly been analysed, the suitable combined framework for the lean-green approach can be defined. Then, Hypotheses H3a–c will model the contribution of the proposed lean-green approach towards the operational, social and environmental performances, respectively. Finally, Hypotheses H3, H4 and H5 relate the operational, social and environmental performances with financial performance, respectively. In the following sections, each set of hypotheses is described. Table 1 presents a summary of the research hypotheses included in the proposed conceptual framework.

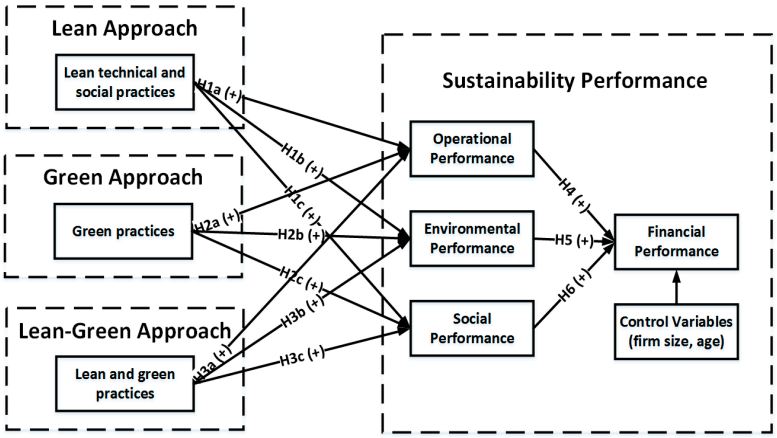

Figure 2. Proposed theoretical manufacturing framework.

Table 1. Summary of research hypotheses.

No	Hypothesis	Type of Hypothesised Relationship
H1a	Lean technical and social practices positively influence operational performance.	Direct (+)
H1b	Lean technical and social practices positively influence environmental performance.	Direct (+)
H1c	Lean technical and social practices positively influence social performance.	Direct (+)
H2a	Green practices positively influence operational performance.	Direct (+)
H2b	Green practices positively influence environmental performance.	Direct (+)
H2c	Green practices positively influence social performance.	Direct (+)
H3a	Lean practices moderate the relationship between green practices and operational performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.	Interaction (+)
H3b	Lean practices moderate the relationship between green practices and environmental performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.	Interaction (+)
H3c	Lean practices moderate the relationship between green practices and social performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.	Interaction (+)
H4	Operational performance is positively related to economic performance.	Direct (+)
H5	Environmental performance is positively related to economic performance.	Direct (+)
H6	Social performance is positively related to economic performance.	Direct (+)

The development of the hypotheses is based on the literature review.

4.1. Lean Practices and Sustainability Performance

Operational performance improvements are, by nature, the main focus of lean social and technical practices, since they consist in a widely accepted and implemented set of practical manufacturing tools, techniques and methods, focused on reducing costs and improving product and delivery qualities from customers' point of view. There are plenty of literature studies addressing operational performance from the lean perspective [41–43]. In this context, it is straightforward to state that:

H1a: *Lean technical and social practices positively influence operational performance.*

Although lean practices have not been aimed at doing so, they can lead to different environmental benefits. The successful achievement of lean objectives can lead to environmental performance improvements. In this regard, some observations can be made. On one hand, it is important to highlight that these improvements can often be interpreted as spin-offs being subjected to different factors, such as the actual success in reaching all the required lean objectives that combined contribute towards improving a particular environmental issue. In addition, these potential environmental improvements are usually not enough to fulfil the environmental standards and local regulations [44]. On the other hand, social lean practices, focused in training

and engaging employees, as well as technical lean practices, focused on organising and cleaning the working area, generate a proper working environment to reach greener results, such as a cultural background that allows for waste reduction and pollution prevention [6,7,9,10,45]. In this sense, the following hypothesis can be made:

H1b: *Lean technical and social practices positively influence environmental performance.*

Lean practices, either social or technical, promote employee, supplier and customer engagement. Regarding employees' engagement, lean practices, such as continuous improvement, are highly correlated with human resources management, including training, empowering, evaluating and rewarding employees, either individually or as a team [45], facilitating employees' self-development [46]. In this context, techniques such as small group problem solving encourage them to become involved in decision-making processes, giving them the power to propose improvements not only in their own tasks but also in the whole production process [47–51]. In addition, some other lean practices, such as 5S, help employees by providing a healthier and safer working environment. Regarding supplier partnership, the lean environment favours information sharing, commitment over an extended period and sharing the risks and rewards of the relationship [49,51,52]. Regarding customers, lean practices identify their needs and take them into account throughout the whole production process [46,49,51]. The following hypothesis can then be stated:

H1c: *Lean technical and social practices positively influence social performance.*

4.2. Green Practices and Sustainability Performance

Green practices are mainly aimed at improving environmental performance of the firms. In this context, the correlation between green practices and operational performance has not been properly addressed in the literature [53]. Despite this literature gap, there some green practices, such as the ones devoted to the product design such as DfE and process planning, that can be positively correlated to the operational performance improvements. In this sense, the following hypothesis can be made:

H2a: *Green practices positively influence operational performance.*

Green practices are aimed at reducing the environmental footprint throughout the entire product life cycle, being responsible for their product until its EOL. In particular, green practices include eliminating CO_2 emissions and hazard substances, minimising water, energy and resource consumption, producing eco-friendly products, applying environmentally friendly EOL strategies, and ensuring a safe, clean and healthy workplace, among others. In this context, it is straightforward to state that:

H2b: *Green practices positively influence environmental performance.*

Green practices are focused on the safety and health of the society as a whole as well as in being responsible for the product footprint throughout its entire life cycle. Green practices can help companies' social performance from both the external and internal points of view. On one hand, adopting environmentally friendly practices improves the companies' positive image and reputation. This increases sales, since brand reputation plays a crucial role in consumer decisions in the sense that environmentally conscious consumers are more willing to buy eco-friendly products and tend to engage with companies that produce them [54]. On the other hand, since green practices aim at reducing material wastage and hazardous emissions, they can provide employees a healthier, cleaner and safer workplace and local society a healthier environment. It is then possible to state that:

H2c: *Green practices positively influence social performance.*

4.3. The Joint Effect of Lean and Green Practices on Sustainability Performance

In the previous sections, the positive influence of lean and green practices applied individually on the operational, environmental and social aspects of the sustainability

performance was discussed. The proposed theoretical framework proposes a set of Hypotheses (H1a–c and H2a–c) to model and estimate the actual impact of lean and green practices on the different sustainability aspects when applied individually. Although positive, the contributions of both practices towards the different considered sustainability aspects are not enough. In order to simultaneously realise higher performance improvements in all the considered sustainability dimensions, the proposed theoretical framework states that it is necessary to resort to the joint implementation of both lean and green practices. The actual strategy for combining both practices will depend on the existing gap's depth regarding the already achieved lean and green objectives and the particular lean and green techniques chosen for practically implementing the practices. As highlighted by the literature review, the main aspects that should be taken into account in order to synchronise lean and green practices into an integrated framework are:

- Waste minimization;
- Environmental management;
- Resource management;
- Elimination of unnecessary processes.

The combination will be based on the socio-technical system (STS) theory [55] and the synergism principles, which support the idea that a superior level of improvements can be achieved when both practices are applied together in a collaborative environment. In this line, the hypotheses modelling the actual impact that the joint implementation of lean and green practices have on the different sustainability performances are stated in terms of a moderating effect of lean practices on green practice performances.

Operational performance is evaluated in terms of the cost reduction, improved quality, delivery and flexibility as a result of implementing manufacturing practices. Researchers have largely discussed the actual impact of green practices on the operational performance [14,56]. In particular, although in the case of green practices there is a lack of a widely accepted set of methods and techniques aimed at addressing specific operational aspects of the firm in contrast to the case of lean practices, green practices have a holistic perspective, developing green models capable of addressing the manufacturing issues considering all the companies' activities as a unified working system [4,14]. In this way, the implementation of specific lean manufacturing techniques within a green context can lead to improvements in specific operational aspects. In such a situation, lean practices will moderate the operational performance (by implementing more specific techniques) of the green practices, yielding to further improvements, and making the following hypothesis feasible:

H3a: *Lean practices moderate the relationship between green practices and operational performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.*

Environmental performance can be evaluated in terms of the efficiency of a company to reduce the environmental footprint throughout the entire product life cycle. Although this is an objective that can be reached by applying green practices, lean practices can help towards generating a proper organisational culture and a suitable working environment, allowing for a more efficient implementation of such green practices and enhancing their results [6,7,9,10,57]. In this context, lean practices can act as moderating factors towards reaching further improvements, since lean employees are empowered, being more willing to adopt different and new practices, while lean working places and processes are more flexible, making it easier to modify them. Then, companies working under lean conditions will be able to take more advantage of the implementation of green practices, making it important to implement them in a combined and synergistic framework in order to reach better and more sustainable environmental performance. Based on these comments, the following hypothesis can be stated:

H3b: *Lean practices moderate the relationship between green practices and environmental performance in such a way that the positive impact of green practices on environmental performance is stronger when lean practices are implemented.*

Green practices which aim to reduce wastes and hazardous emissions help to improve employees' working environments, making it safer and healthier. If these practices are implemented within a lean culture where the work is standardised, the processes are efficient, the individual and team tasks are fairly distributed, and the working areas are well organised according to the 5S, making them ordered and clean. It is likely to obtain further improvements in comparison with the ones obtained in a working environment that is not lean. In addition, green practices also contribute to the local community quality of life in terms of reducing emissions, preventing pollution, DfE and taking care of the environmental impact of the products until their EoL. For instance, lean practices, which allow for product modularization and parts standardization, simplify the production process, helping to reduce wastes and energy consumption and contributing towards the eco-friendly nature of the produced products. In addition, lean practices promote face-to-face planning and communication with suppliers, which helps companies to be responsible for suppliers' environmental issues. Finally, lean practices are highly costumer oriented, keeping a healthy interaction with costumers aimed at satisfying their needs. In this line, lean practices can not only help to identify to what extent customers are willing to buy green products, but also to the diffusion of the companies' green initiatives. Then, the following hypothesis can be made:

H3c: *Lean practices moderate the relationship between green practices and social performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.*

4.4. The Interrelationship among Sustainability Performance

The proposed theoretical framework models the sustainability performance in terms of the TBL sustainability model, taking into account the economic, environmental and social performances. In addition, breaking down the economic performance into two performances, namely, the operational and financial performances, is proposed. Finally, in order to model the sustainability performance as a whole, the contributions of the operational, environmental and social performances to financial performance are taken into account by Hypotheses H4, H5, H6, respectively, as shown in Figure 2. These hypotheses are described as follows.

The relationship between operational performance and financial performance has largely been studied [54], being almost straightforward. In general, the more efficient the operational aspects of a firm are, in terms of resource, time, and energy consumption, the higher the cost savings and the better the quality of the produced product. More specifically, improvements in the operational performance in terms of improvements in processes and equipment, such as the use of "error-proof" equipment, cycle time reduction, availability and reliability of machines, and use of cellular manufacturing, avoid incorrect processing and overprocessing. This helps to produce higher-quality products and reduce the material and energy usage as well as the waste production, reducing the production costs, making companies more competitive and profitable, and improving the company's financial performance. In addition, improvements in the operational performance in terms of improvements in planning and control strategies, such as pull-flow control, overlapped production, visual control of the shop floor, small lot sizing, scheduling, levelled production, and inventory reduction, contribute to reduce wastes in overproduction. In particular, planning and control practices can reduce the materials and components used throughout the manufacturing operations, reduce the work in process and floor space utilization, and reduce the damaged products without affecting the delivery time. In this way, planning and control practices can lead to higher financial performance by reducing in-process

wastes and faulty materials and by improving the work schedule. In this line, the following hypothesis can be made:

H4: *Operational performance is positively related to financial performance.*

The profitability of practices that allow for improving environmental performance has largely been called into question by practitioners. Nevertheless, there are those that agree that improvements in environmental performance can lead to improvements in the financial aspects in terms of costs savings through a more efficient system, leading to a positive impact on the ROI [58] and through avoiding paying high taxes and punishments applied by local regulations and international standards. In addition, an improved environmental performance would result in a better firm's image, making it more competitive and, consequently, more profitable. Then, the following hypothesis can be stated:

H5: *Environmental performance is positively related to financial performance.*

Social performance can be evaluated from the employees' point of view and from the community point of view. In the first case, if employees are trained, involved and empowered, they will be able to work more efficiently, being willing to learn and adopt new manufacturing strategies, and even to propose their own ideas to improve the manufacturing processes. In the second case, if the firm interacts with the community, adding value to their culture and daily life, the image of the firm will be improved, and the community will be engaged with the firm's principles and will buy its products. In both cases, the described socially improved contexts will lead to financial improvements. In this sense, it can be stated that:

H6: *Social performance is positively related to financial performance.*

5. Quantitative Analysis and Discussion for the Case of the Manufacturing Sector in Saudi Arabia

Industry and production of a country are great economic indicators of its development, as well as important indicators of its autonomy and position at the world level. As highlighted in the introduction of this paper, the focus as well as the collection of primary data are from Saudi Arabia. In Saudi Arabia, modernisation and industrial diversification are taking place at a rapid pace, accompanying the modernisation of the country. In addition, the bet in new sectors as well as the greater intervention of the population in the country's decisions has also contributed to the industrial modernisation. However, the increased industrialisation has contributed to increased environmental and sustainability concerns. While the global market urges to move towards more advanced manufacturing practices, including the implementation of lean, green and lean-green practices, such practices are still in their early stages in most Saudi companies [59]. In this context, the lean-green combined theoretical manufacturing framework proposed in this paper is intended to encourage Saudi companies to move towards implementing new and innovative manufacturing procedures, providing them useful tools to actually improve their economic, environmental and social performances. The main objective of the survey conducted within the framework of this paper and analysed in this section is then to practically test and validate the theoretical manufacturing framework proposed in Figure 1 by studying, describing and evaluating the perception of Saudi practitioners regarding the introduction of lean, green or lean-green approaches in their business, their expected benefits and issues, and their impact on the outcomes in terms of economic, environmental and social performances.

5.1. Survey Structure

The conducted survey is based on an ad hoc designed questionnaire including 273 questions (multiple choice Likert scale questions and open text questions) addressing five main aspects:

- Personal and business information;
- Impact of lean practices on business outcomes;

- Impact of green practices on business outcomes;
- Knowledge about lean-green practices as well as their impact on business outcomes;
- Impact of operational, environmental and social performances on financial performance.

The questions included in the questionnaire were derived from a thorough literature review. Principal components analysis (PCA) was used for validating what the survey is actually measuring. It is used to identify the underlying elements measured by the survey, determining the most representative themes addressed by the questions. The particular selection of the PCA analysis relies on the fact that PCA is a simple, efficient and non-computationally expensive statistic tool, capable of representing large sets of data by smaller and easier-to-digest ones that can be more rapidly and readily analysed. In this way, only the most important (principal) elements of the survey are left to be further analysed, avoiding the analysis of unnecessary elements.

Based on such PCA analysis, Likert scale questions have five possible answers, containing thirteen principal components for their further analysis. Table 2 shows a summary of the thirteen main components and the number of questions that account for each one of them. The complete questionnaire is available as supplemental material in the present paper.

Table 2. Thirteen principal components used for data analysis.

Hypothesis
Lean practices towards Operational Performance → 27 questions
Lean practices towards Environmental Performance → 17 questions
Lean Practices towards Social Performance → 27 questions
Green Practices towards Operational Performance → 26 questions
Green practices towards Environmental Performance → 29 questions
Green Practices towards Social Performance → 15 questions
Lean-green Approach: Understanding → 49 questions
Lean-green Approach towards Operational Performance → 12 questions
Lean-green Approach towards Environmental Performance → 6 questions
Lean-green Approach towards Social Performance → 10 questions
Operational Performance towards Financial Performance → 9 questions
Environmental Performance towards Financial Performance → 4 questions
Social Performance towards Financial Performance → 8 questions

5.2. Survey Description

The sample population surveyed in this study is composed of 102 employees from 15 different businesses in Saudi Arabia. The survey was distributed to employees in a wide range of job positions, as shown in Table 3.

Table 3. Job position of surveyed respondents among all businesses.

Job Position	Count	N %
Tech Engineer	25	24.5%
Chemical Analyst	3	2.9%
Department Chief	3	2.9%
Production	21	20.6%
Engineer	14	13.7%
Manager	7	6.9%
Operations	17	16.7%
Department Manager	2	2.0%
Account	2	2.0%
Assistant	2	2.0%
Driver	2	2.0%
Technician	4	3.9%

Including a wide range of business activities in the sample is crucial in order for the survey to cover the real business scenario as much as possible. In particular, the conducted survey includes employees from 11 business activities. However, these activities are not equally represented in the survey, being most of the respondents from the chemistry, petroleum, rubber and food industries. The wood and paper industries, on the other hand, are the business activities with the lowest representation. All the business activities represented in the conducted survey are shown in Figure 3. As the focus of the present work is the SMEs in Saudi Arabia, all companies participating in this survey were SMEs, with the number of employees ranging from 5 to 70. The targeted employees for completing the questionnaire were the ones with the lengthiest service in each organization. In this sense, it can be said that the sampled employees should be able to respond to the questionnaire based on a deep know-how of their business activities. Figure 4 shows the working experience of the respondents in their respective organizations.

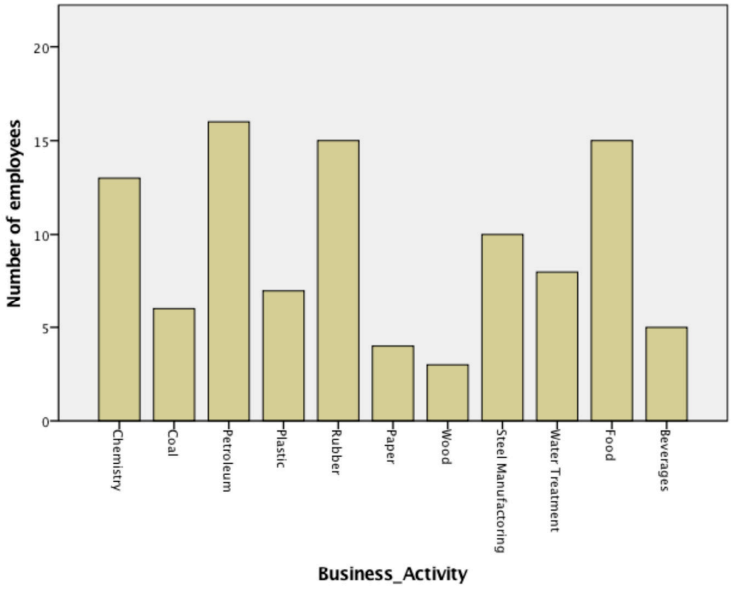

Figure 3. Business activities included in the survey.

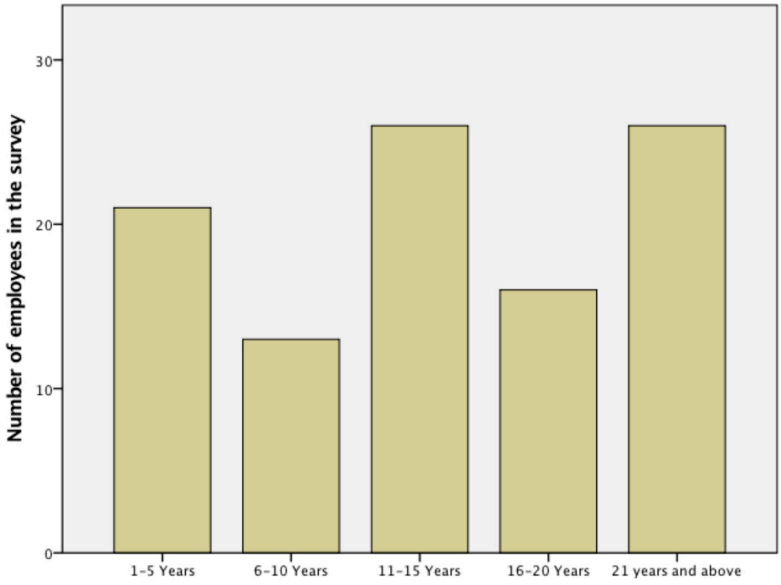

Figure 4. Years of professional experience for all employees surveyed across all business.

The questionnaire data for all the included questions are summarised, based on a PCA analysis, according to 13 principal components aiming to access specific questions regarding the lean, green and lean-green approaches. In this way, while individual questions are set using a Likert scale with five possible options (Strongly Agree = 1, Agree = 2, Don't Know = 3, Disagree = 4 and Strongly Disagree = 5), the thirteen main components are the average score for all sub-questions of the main components. In Table 4, the 13 principal components of the questionnaire, referred to as dependent variables (DV), are listed.

Table 4. Main components assessed by the questionnaire that were used for data analysis hypothesis testing.

Dependent Variable (DV) Description	DV Number
Lean practices towards Operational Performance	DV1
Lean practices towards Environmental Performance	DV2
Lean Practices towards Social Performance	DV3
Green Practices towards Operational Performance	DV4
Green practices towards Environmental Performance	DV5
Green Practices towards Social Performance	DV6
Lean-green Approach: Understanding	DV7
Lean-green Approach towards Operational Performance	DV8
Lean-green Approach towards Environmental Performance	DV9
Lean-green Approach towards Social Performance	DV10
Operational Performance towards Financial Performance	DV11
Environmental Performance towards Financial Performance	DV12
Social Performance towards Financial Performance	DV13

5.3. Survey Validation

5.3.1. Testing the Assumptions

Statistical tests usually require assumptions to be fulfilled in order to prove their validity. Among them, assuming the sample is normally distributed or large enough (usually higher than 30 individuals or observations) are the most common ones. In addition, the linearity assumption is important in the case of linear regression modelling, since in such a case, the outliners can have a significant impact on the models. Finally, the homoscedasticity assumption is also helpful to simplify the mathematical computation; normality, linearity and homoscedasticity are tested.

- Normality Test

In general, the larger the sample size, the closer the distribution to the normal one. In particular, most statistical and mathematical tests are based on the central limit theorem which indicates that, provided the sample size is large enough, the means of samples obtained using a random sampling with replacement are distributed normally, regardless of the population distribution. To access normality of data distribution for the 13 main components of the questionnaire, the four most common tests of normality, viz., skewness, Kurtosis [5], Kolmogorov–Smirnov, and Shapiro–Wilk [60], are used. The results of these tests are shown in Table 5. It can be seen that when evaluating the variable distribution based on the skewness and Kurtosis tests, most of them result to be not normally distributed. This is not surprising, since they are the mean value of a Likert scale, in which the central measure (Don't know = 3) is the less likely to occur. On the other hand, when evaluating the variable distribution based on the Kolmogorov–Smirnov and Shapiro–Wilk tests, the data can be considered as normal distributed ($p < 0.05$ for all variables). These findings are probably due to the sample size (n = 102) rather than due to a "perfect" normal distribution [61].

Table 5. Normality tests for the 13 dependent variables in the study.

	Skewness			Kurtosis			Kolmogorov–Smirnov	Shapiro–Wilk
	Statistic	**Std. Error**	**Z-Score**	**Statistic**	**Std. Error**	**Z-Score**	**Sig. (p Value)**	**Sig. (p Value)**
DV1	−0.578	0.239	−2.410	1.171	0.474	2.470	<0.001	<0.001
DV2	−0.790	0.239	−3.305	0.149	0.474	0.314 *	<0.001	<0.001
DV3	−0.221	0.239	−0.925 *	1.596	0.474	3.367	<0.001	<0.001
DV4	−1.047	0.239	−4.381	0.844	0.474	1.781 *	<0.001	<0.001
DV5	−0.843	0.239	−3.527	1.070	0.474	2.258	<0.001	<0.001
DV6	0.015	0.239	0.063 *	0.008	0.474	0.017 *	<0.001	0.015
DV7	−0.446	0.239	−1.866 *	1.445	0.474	3.049	<0.001	<0.001
DV8	2.019	0.239	8.448	12.142	0.474	25.616	<0.001	<0.001
DV9	−0.003	0.239	−0.013 *	0.543	0.474	1.146 *	<0.001	0.01
DV10	−0.735	0.239	−3.075	0.826	0.474	1.743 *	<0.001	<0.001
DV11	−0.481	0.239	−2.013	1.346	0.474	2.840	<0.001	<0.001
DV12	0.141	0.239	0.590 *	1.746	0.474	3.684	<0.001	<0.001
DV13	−0.337	0.239	−1.410 *	0.669	0.474	1.411	<0.001	<0.001

* Significant values are $p < 0.05$.

- Linearity Test

To test for linearity, a correlation matrix was constructed using Pearson's bivariate correlation among all 13 variables. The obtained correlation coefficients are shown in Table 6. It can be seen that, with exception to only three correlations (highlighted in boldface), all the variables are significant and positively correlated, with $p < 0.05$.

Table 6. Linearity test using Pearson's bivariate correlation among the 13 variables.

Kendall's Tau	**DV2**	**DV3**	**DV4**	**DV5**	**DV6**	**DV7**	**DV8**	**DV9**	**DV10**	**DV11**	**DV12**	**DV13**
DV1	0.317	0.646	0.334	0.374	0.445	0.232	0.425	0.270	0.652	0.313	0.345	0.312
DV2		0.433	0.524	0.479	0.372	0.421	0.500	0.557	0.393	0.442	0.209	0.472
DV3			0.363	0.434	0.422	0.301	0.562	0.338	0.676	0.458	0.442	0.246
DV4				0.584	0.262	0.474	0.296	0.350	0.401	0.237	0.437	0.387
DV5					***0.133***	0.436	0.450	0.416	0.279	0.335	0.312	0.287
DV6						0.424	0.297	0.438	0.577	0.585	0.250	0.558
DV7							***0.096***	0.496	0.214	0.415	0.240	0.323
DV8								0.478	0.461	0.418	0.283	0.446
DV9									0.306	0.394	***−0.051***	0.441
DV10										0.452	0.529	0.357
DV11											0.363	0.570
DV12												0.228
DV13												

- Homoscedasticity

Homoscedasticity is accessed for the 13 variables, using their residuals. Residuals are the differences between the values predicted assuming normal distribution and the values obtained from the real data. In particular, homoscedastic data should have residual values that are normally distributed. In order to test so, standardised z-score values are calculated for each of the 13 variables, and then, the normality of these standardised values is accessed. Here, although the data corresponding to the residuals are not perfectly parametric, parametric tests can still be employed since the size of the used sample is big enough. The obtained results regarding the residual values distribution are shown in Table 7. For the skewness and Kurtosis tests, a z-score value between −1.96 and 1.96 is associated with normal distributed data. Values in this interval are highlighted in boldface. According to the

results for the Kolmogorov–Smirnov and Shapiro–Wilk tests, where a $p < 0.05$ is associated with a normal distribution, most of the residual values are normally distributed.

Table 7. Normality tests for the residuals of all 13 variables in the study.

	Skewness			Kurtosis			Kolmogorov–Smirnov	Shapiro–Wilk
	Statistic	**Std. Error**	**Z-Score**	**Statistic**	**Std. Error**	**Z-Score**	**Sig. (p Value)**	**Sig. (p Value)**
DV1	−0.578	0.239	−2.410	1.171	0.474	2.470	<0.001	<0.001
DV2	−0.790	0.239	−3.305	0.149	0.474	***0.314*** *	<0.001	<0.001
DV3	−0.221	0.239	***−0.925*** *	1.596	0.474	3.367	<0.001	<0.001
DV4	−1.047	0.239	−4.381	0.844	0.474	***1.781*** *	<0.001	<0.001
DV5	−0.843	0.239	−3.527	1.070	0.474	2.258	<0.001	<0.001
DV6	0.015	0.239	***0.063*** *	0.008	0.474	***0.017*** *	<0.001	0.015
DV7	−0.446	0.239	***−1.866*** *	1.445	0.474	3.049	<0.001	<0.001
DV8	2.019	0.239	8.448	12.142	0.474	25.616	<0.001	<0.001
DV9	−0.003	0.239	***−0.013*** *	0.543	0.474	***1.146*** *	<0.001	0.01
DV10	−0.735	0.239	−3.075	0.826	0.474	***1.743*** *	<0.001	<0.001
DV11	−0.481	0.239	−2.013	1.346	0.474	2.840	<0.001	<0.001
DV12	0.141	0.239	***0.590*** *	1.746	0.474	3.684	<0.001	<0.001
DV13	−0.337	0.239	***−1.410*** *	0.669	0.474	1.411	<0.001	<0.001

* Significant values are $p < 0.05$.

5.3.2. Testing Common Method Bias and Non-Response Bias

The common method bias, which is a bias of underestimation or overestimation of measure, is associated with the error that occurs when respondents of a questionnaire have the will to provide positive answers to the researcher in order to better suit the research objectives. In particular, the common method bias can be detected based on a principle that establishes that variations in responses are caused by the instrument rather than by the actual predisposition of the respondents [62]. Based on this principle, the Harman test, which is not capable of directly testing (or controlling) the method bias, but allows for testing the respondents' response bias, can still be used to test for common method bias.

According to the Harman test, bias is considered to occur either when the solution results in a single extracted factor or when a single factor extracts most of the variance from the set of variables. The Harman one-factor analysis is then used to test for common method bias by testing whether a single factor is accountable for variance in all the data set or not. In the analysis performed in this section, the Harman test is performed by using PCA as the extraction method [63]. Table 8 shows the results of such a test. It can be seen that only one factor (number 1) is responsible for more than 75% of the variance in the tests. This suggests that respondents may have answered with the aim of fulfilling the study objectives or may have claimed some interests or personal views rather than a truthful report of the actual business situation.

Table 8. Harman's single factor for total variance explained using principal component analysis as extraction method.

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.832	75.628	75.628	**9.602**	**73.865**	**73.865**
2	0.851	6.549	82.178			
3	0.633	4.873	87.050			
4	0.469	3.606	90.656			
5	0.348	2.680	93.336			
6	0.220	1.689	95.025			
7	0.192	1.476	96.501			
8	0.133	1.024	97.526			
9	0.127	0.981	98.506			
10	0.092	0.711	99.217			
11	0.045	0.346	99.562			
12	0.033	0.256	99.818			
13	0.024	0.182	100.000			

5.3.3. Evaluating the Measurement Model Value

To evaluate the model measurement value, the reliability and validity of the questionnaire is assessed. In particular, the reliability of the measurement model is tested using statistical methods, while its validity is addressed from an empirical point of view. According to the survey validation process introduced by Tehseen et al. [63], an analysis based on carefully selected statistical methods should be used to test the reliability of the survey. In the case of the conducted survey, reliability is accessed based on the well-known Cronbach's Alpha test. In general, reliability tests aim to access whether two observations in the same study or questionnaire equivalent to each other in terms of the construct and measurement tools lead to an equivalent outcome when comparing their outcomes to each other. In order to do so, the Cronbach's Alpha test splits data into two equal parts and compares variations in these two parts. The Cronbach's Alpha test results in reliability values varying between 0 and 1, with values higher than 0.7 usually considered acceptable for Likert scale data [40]. For the conducted survey, a Cronbach's Alpha value of 0.972 was obtained, as shown in Table 9, demonstrating excellent reliability of the measurement tool.

Table 9. Reliability analysis using Cronbach's Alpha.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.962	**0.972**	13

In order to further prove the reliability of the conducted survey, the Cronbach's Alpha test is strengthened by performing "if item deleted". In this case, the obtained results still remain higher than 0.9, suggesting an excellent reliability of the survey, even if only one item is analysed. Table 10 shows all the results obtained in the case of one item deleted, performed for all the main components in the analysis.

Table 10. Reliability analysis using Cronbach's Alpha if item deleted.

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha If Item Deleted
Lean practices towards Operational Performance	35.1870	57.730	0.897	**0.958**
Lean practices towards Environmental Performance	35.1123	56.950	0.853	**0.958**
Lean Practices towards Social Performance	35.3104	57.473	0.923	**0.957**
Green Practices towards Operational Performance	35.0186	56.807	0.866	**0.958**
Green practices towards Environmental Performance	35.1188	57.099	0.888	**0.958**
Green Practices towards Social Performance	35.3410	57.393	0.804	**0.959**
Lean-green Approach: Understanding	35.1664	56.580	0.906	**0.957**
Lean-green Approach towards Operational Performance	35.1428	53.086	0.664	**0.969**
Lean-green Approach towards Environmental Performance	35.2081	56.653	0.796	**0.959**
Lean-green Approach towards Social Performance	35.0409	55.578	0.924	**0.956**
Operational Performance towards Financial Performance	35.1302	55.837	0.916	**0.957**
Environmental Performance towards Financial Performance	34.7318	56.724	0.574	**0.967**
Social Performance towards Financial Performance	35.2441	56.580	0.861	**0.958**

5.4. Hypothesis Testing

In order to test the hypotheses supporting the theoretical framework proposed in Figure 1, the one-sample binomial test is used to compare the proportion of positive and negative responses. The variables are codified considering the nature of the Likert scale. Mean values for the several composite scores are coded as "Yes" if respondents mainly respond Agree or Strongly Agree (mean ranging from 0 to 2.50) to the subset of questions and "No" if respondents mainly respond Disagree or Strongly Disagree (means ranging from 2.51 to 5) to the subset of questions. The one-sample binomial test assumes a null hypothesis in which the proportion of positive and negative responses is equal, which means a probability of 0.5 for both "Yes" and "No" responses. With a p value lower than 0.05, the null hypothesis must be rejected, making it possible to assume that differences in the proportion of positive and negative responses are significantly different.

In addition, the relationship between different business main activities and a positive perception regarding lean, green and lean green has also been tested. In particular, the Chi-square test, which compares the proportions between two or more groups, in order to identify whether at least one group is different from the other ones, was employed. In order to apply such a test, the business activities and the lean, green and lean-green positive perceptions are coded as dichotomous variables, and the Chi-square test is performed.

5.4.1. Testing the Impact of Lean Practices

The impact of lean practices in business is assessed by a set of questions directly associated with the identified success factors and the encountered barriers when implementing lean practices, as well as with the perceived benefits for business, environment and society.

H1a: *Lean technical and social practices positively influence operational performance.*

The results of the one-sample binomial test are shown in Figure 5. It can be seen that a p value of $p < 0.05$ was obtained, meaning that the null hypothesis should be rejected. This shows that there are significant differences in the counting of positive and negative responses. In addition, the proportion corresponding to positive responses is higher than the one corresponding to negative ones. These results suggest that, according to respondents, lean technical and social practices positively influence operational performance. Hypothesis H1a is thus confirmed.

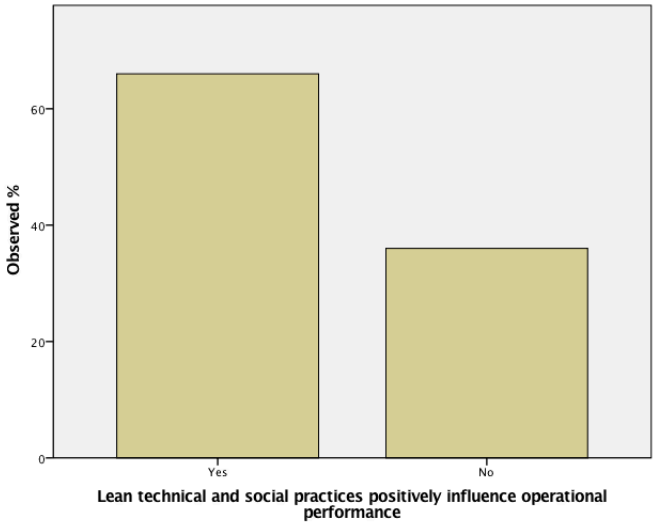

Figure 5. One sample binomial test results for H1a.

The results regarding how lean practices are perceived within the context of the different business activities are shown, in terms of the Chi-square test, in Table 11. It can be seen that respondents working in activities related to steel manufacturing and paper do not agree that lean technical and social practices positively influence the operational performance. In addition, the results for all the other surveyed business activities resulted to be not statistically significant.

Table 11. Chi-square test comparing the proportion of agreements with the statement that lean technical and social practices positively influence operational performance among different business activities.

Business Activity	Lean Technical and Social Practices Positively Influence Operational Performance	
	Yes %	**No %**
Chemistry	69.2%	30.8%
Coal	66.7%	33.3%
Petroleum	68.8%	31.2%
Plastic	85.7%	14.3%
Rubber	66.7%	33.3%
Paper	**50.0%**	**50.0%**
Wood	66.7%	33.3%
Steel Manufacturing	**30.0%**	**70.0%**
Water Treatment	66.5%	37.5%
Food	66.7%	33.3%
Beverages	80.0%	20.0%

Pearson Chi-Square tests. Sig. = 0.6451/degrees of freedom = 10/test statistic = 7.832.

Based on the results related to H1a, the majority of respondents are already aware of the positive effects of lean technical and social practices on the operational performance. Such conclusions are further highlighted through a thorough analysis of the responses that suggest that employees in the participating companies, although being concerned with the

several challenges the implementation of lean practices implies, they do recognise that the lean approach can have a positive impact on the production and financial performances of the companies.

These results are promising when compared with the previous results published in the literature reporting that only about 20% of Saudi employees have a positive understanding of the influence of lean practices on operational performance. In addition, these results are also promising when compared with previous quantitative results published in the literature reporting that only about 20% of Saudi employees have a positive understanding of the influence of lean practices on operational performance [5,64]. For instance, a study including both private and public Saudi organizations has found that only less than 10% of the participants were fully aware of lean benefits [64]. In addition, another study by Albliwi et al. [5] has found that productivity and product quality were the least improved variables when implementing lean practices. In this context, the results obtained by the conducted survey show that, in the last years, Saudi employees' awareness about the operational benefits of implementing lean practices has increased. These results are very helpful to encourage all Saudi companies, the ones that are already implementing lean practices as well as the ones that are still evaluating to do so, to actually keep their efforts in this direction.

H1b: *Lean technical and social practices positively influence environmental performance.*

The results of the one-sample binomial test are shown in Figure 6. It can be seen, on one hand, that the one-sample binomial test resulted in $p < 0.05$ and, on the other hand, that the proportion of positive responses ("Yes") in the frequency graph is higher than the one corresponding to the negative ones. Since these results are the same as in the case of H1a, the same comments stand, arriving to the conclusion that Hypothesis H1b is true. Finally, in this case, when evaluating the different perceptions regarding the influence of lean practices in environmental performance across the different types of business activities based on the Chi-Square test, no significant differences were found ($p = 0.081$).

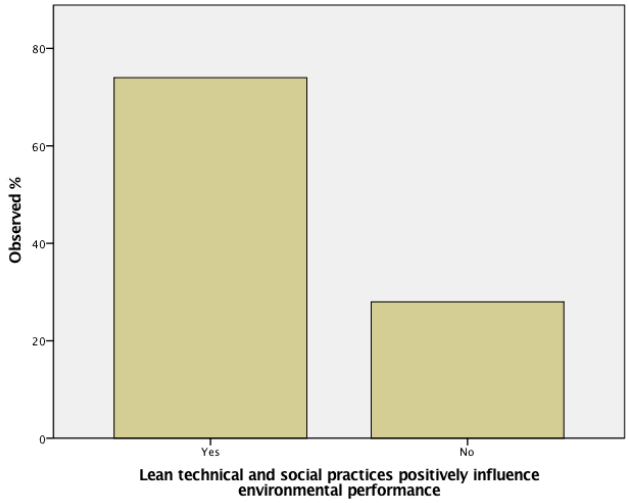

Figure 6. One sample binomial test results for H1b.

According to the available literature, the majority of environmental impact of business processes comes from the materials used in business, such as global warming, soil acidification, carcinogenesis material usage, respiratory effects or smog, and common indicators. In addition, different studies, such as the one in [65], state that transportation, equipment manufacturing and combustion are the major contributors only for ozone depletion. In Saudi Arabia, most industries use raw material in their production. Previous findings published in the literature for this particular kind of industry have shown that a highly efficient implementation of lean practices is needed towards achieving a significant impact on environmental performance. In this context, although the majority of the respondents of the conducted survey agree with the fact that lean practices, which mainly aim at waste reduction, can have a positive impact on

environmental issues, there is a percentage of 27% of respondents that is still reluctant to believe that this impact can be significant enough, especially, when dealing with raw material pollution.

Analysing the responses to the questionnaire highlighted that only a few companies in Saudi Arabia, such as the ones focused on plastic, chemistry and beverages, mention waste reduction and management as the main advantages of implementing lean practices. In this way, although waste reduction and management are not strictly related to environmental issues, these companies perceive a potential environmental benefit of lean practices. Nevertheless, when quantitatively evaluating the different perceptions regarding the influence of lean practices in environmental performance across the different types of business activities based on the Chi-Square test, no significant differences were found ($p = 0.081$).

H1c: *Lean technical and social practices positively influence social performance.*

The results of the one-sample binomial test, shown in Figure 7, have a $p < 0.05$, while the proportion of positive responses ("Yes") in the frequency graph is lower than the one corresponding to the negative ones. In this context, hypothesis H1c is false. In addition, when evaluating the different perceptions regarding the social benefits of implementing lean practices across the different types of business activities based on the Chi-Square test, no significant differences were found ($p = 0.081$).

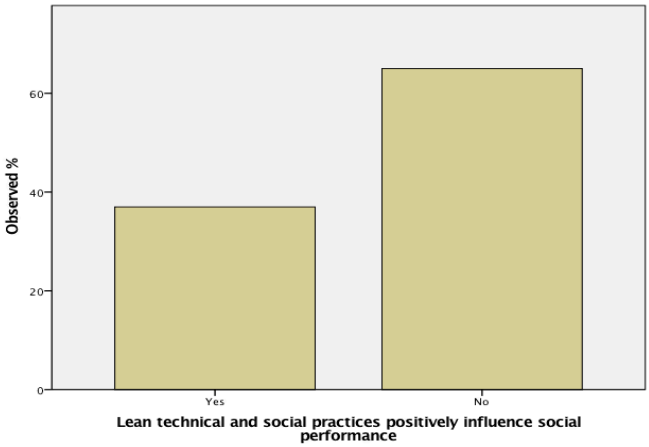

Figure 7. One sample binomial test results for H1c.

Analysing the responses to the questionnaires, highlighted as the most concerning issue identified by employees, is the lack of leadership and management. Social performance and social responsibility are still a long way to go in Saudi organisations [66]. Mandurah et al. [67] found that Saudi intermediate level managers are well aware of social responsibility and its importance in improving social performance. However, top managers do not share the same view about social responsibilities, being less interested in implementing social performance indicators [68]. This causes conflicting expectations, which may be an explanation for the poor results found in the conducted survey regarding lean practices influencing social performance.

5.4.2. Testing the Impact of Green Practices

The impact of green practices in business is accessed by a set of questions directly associated with the identified success factors and the encountered barriers when implementing green practices, as well as with the perceived benefits for business, environment and society. The perception of Saudi employees regarding the implementation of green practices was identified after analysing the responses to the questionnaires. On one hand, they are highly concerned about the cost and operational challenges that green practices implementation implies. On the other hand, they believe that, provided that the financial and operational barriers can be sorted, green practices can lead to great business opportunities. In order to complement this qualitative analysis, a quantitative analysis of the impact of green practices in the companies' performance from the employees' point of view is conducted in this section.

The main aim of this quantitative analysis is to quantify to what extent employees expect positive outcomes when implementing green practices in terms of operational, environmental and social performances. This is performed by testing the Hypotheses (H2a, H2b and H2c) supporting the theoretical framework.

H2a: *Green practices positively influence operational performance.*

The results of the one-sample binomial test, shown in Figure 8, are the same as in the cases of hypotheses H1a and H1b. In this context, the same comments stand, arriving to the conclusion that Hypothesis H2a is true. This result shows that Saudi employees are highly concerned about the operational barriers encountered when trying to implement green practices, such as the lack of know-how and the huge investment. They recognise that green practices can have a positive impact on some operational aspects, such as standardising of processes and improving efficiency in terms of manufacturing and volume outcomes.

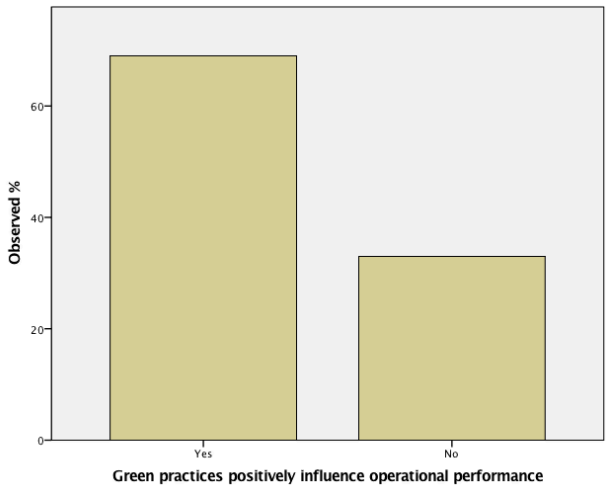

Figure 8. One-sample binomial test results for H2a.

The obtained results regarding how green practices are perceived within the context of the different business activities are shown, in terms of the Chi-square test, in Table 12. It is possible to see that respondents working in activities related to coal, steel manufacturing and beverages do not agree that green practices can positively influence the operational performance.

Table 12. Chi-square test comparing the proportion of agreement with green practices towards operational performance among different business activities.

Business Activity	Green Technical and Social Practices Positively Influence Operational Performance	
	Yes %	**No %**
Chemistry	76.9%	23.1%
Coal	**33.3%**	**66.7%**
Petroleum	81.3%	18.8%
Plastic	85.7%	14.3%
Rubber	86.7%	13.3%
Paper	100.0%	0.0%
Wood	66.7%	33.3%
Steel Manufacturing	**10.0%**	**90.0%**
Water Treatment	100.0%	0.0%
Food	60.0%	40.0%
Beverages	**20.0%**	**80.0%**

Pearson Chi-Square tests. Sig. = 0.001/degrees of freedom = 10/test statistic = 29.409.

Although there is a global tendency of moving towards greener solutions, environmental concerns in Saudi Arabia are not yet the main priority for business management. This is

particularly notorious in business activities that highly depend on raw material, such as coal and steel manufacturing, as the results shown in Table 12 demonstrate. Nevertheless, the results in Table 12 also show that the perception of green practices is changing, showing that Saudi employees working in other type of businesses, such as paper or water treatment related activities, actually perceive some operational benefits associated with the implementation of green practices. Among them, paper and water treatment companies are the more optimistic ones (100%). This is probably due to the fact that companies such as water treatment can take advantage of some green practices to enhance their productive process. For instance, a sub-product (gas) of green practices applied to water treatment can be used as fuel to input into some other stages of the process. In this way, water treatment companies do not only recycle organic waste into fuel, reducing costs and environmental damage, but also optimise their productive process, making it more efficient and less time consuming, and avoiding delays in waiting for external fuel supply.

At this point, it is necessary to highlight that since Saudi companies do not have strong governmental support, there is no clear legislation regarding green standards. In this context, companies tend to adopt green practices by choice rather than by the stakeholders' pressure. In other words, this uncertain situation allows top managers of business activities where green practices are either hard to be implemented or do not achieve the expected ROI to avoid their implementation. The results of the conducted survey, showing that the positive view of Saudi employees on how green practices can influence operational performance strongly depends on the business activity, reflect the current situation of Saudi companies, in terms of top management, governmental support and stakeholder involvement.

H2b: *Green practices positively influence environmental performance.*

The results of the one-sample binomial test, shown in Figure 9, are the same as in the cases of the Hypotheses H1a, H1b and H2a. In this context, the same comments stand, arriving to the conclusion that hypothesis H2b is true. In particular, this result shows that a high rate of employees (more than 60%) believe that green practices can have a positive effect on environmental performance. This is an expected result, since green practices are aimed at improving the environmental aspects of the business and, as such, they should positively influence environmental performance by nature. In addition, the analysis of the responses concluded that Saudi employees mainly associate green practices with environmental issues. In particular, most of the identified green opportunities are related to environmental aspects, such as reducing CO_2 emissions, preventing and minimising waste, re-using, recycling, reducing trash production, and combating climate change. The obtained results regarding how green practices are perceived within the context of the different business activities are shown, in terms of the Chi-square test, in Table 13. It can be seen that respondents working in activities related to petroleum and beverage industries do not agree that green practices can positively influence environmental performance. On the other hand, respondents working in activities related to coal, paper, wood, water treatment and steel manufacturing industries agree that green practices can positively influence environmental performance. Unfortunately, although employees are aware of the potential benefits that green practices can have on environmental performance, the implementation of such practices is still in its early stages in Saudi companies because of the numerous barriers. This, as suggested above, can probably be explained by the fact that most Saudi companies use raw materials in their production processes. These kinds of businesses are, on one hand, very unlikely to be green and, on the other hand, need a very high investment to improve environmental performance in exchange for a relatively small return in achieving this goal.

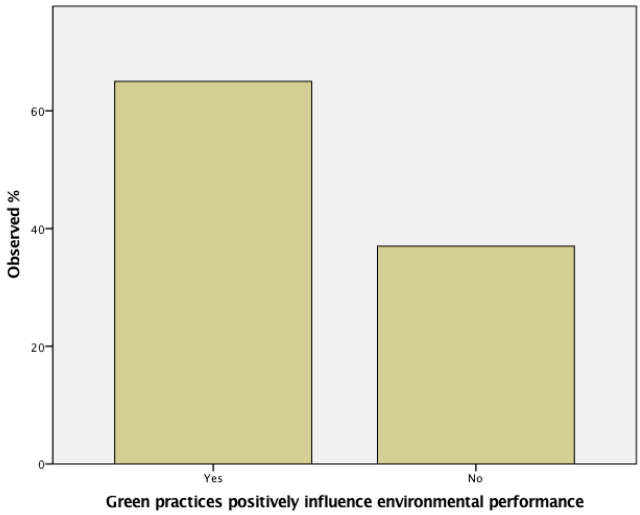

Figure 9. One-sample binomial test results for H2b.

Table 13. Chi-square test comparing the proportion of agreement with green practices towards environmental performance among different business activities.

Business Activity	Green Practices towards Environmental Performance	
	Yes	**No**
	Row N %	
Chemistry	38.5%	31.5%
Coal	100.0%	0.0%
Petroleum	**43.8%**	**56.3%**
Plastic	57.1%	42.9%
Rubber	100.0%	0.0%
Paper	100.0%	0.0%
Wood	100.0%	0.0%
Steel Manufacturing	90.0%	10.0%
Water Treatment	100.0%	0.0%
Food	53.3.0%	46.7%
Beverages	**0.0%**	**100.0%**

Pearson Chi-Square tests. Sig. = 0.001/degrees of freedom = 10/test statistic = 35.462.

The results in Table 13 show that a high rate of employees (more than 60%) believe that green practices can have a positive effect on environmental performance. This is an expected result, since green practices are aimed at improving the environmental aspects of the business and, as such, they should positively influence environmental performance by nature.

H2c: *Green practices positively influence social performance.*

The results of the one-sample binomial test, shown in Figure 10, are the same as in the case of hypothesis H1c. In this context, the same comments stand, arriving to the conclusion that hypothesis H2c is false. In addition, when evaluating the different perceptions regarding the green practices influences on social aspects across the different types of business activities based on the Chi-Square test, no significant differences were found ($p = 0.184$).

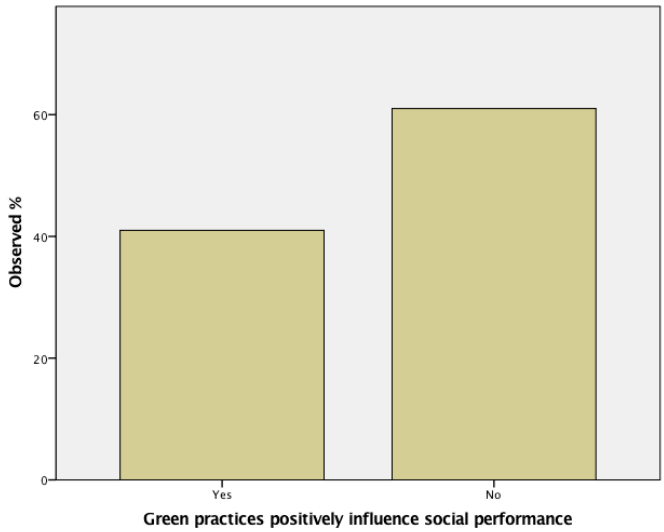

Figure 10. One-sample binomial test results for H2c.

Analysing the responses to the questionnaires has shown that Saudi employees, especially those working in job positions related to technical activities, agree that green practices are tightly related to social aspects in terms of achieving a sustainable local economy, educating and involving women, making communities feel safe, providing job opportunities and employment, enhancing the quality of life of the employees, and developing projects for natural conservation. In addition, it was highlighted that social responsibility is a critical aspect for Saudi companies. The results shown in Figure 9 suggest that, although Saudi employees understand the relationship between green practices and social aspects, they do not believe that they are currently implemented in such a way that the potential benefits can be perceived. In this context, the results obtained here suggest that companies are urged to implement institutional programs towards improving their employees working conditions as well as the local community's living conditions, emphasising focus on vulnerable groups, giving them job opportunities, empowerment and capability to understand and actively participate in the community well-being.

The social impact of a business is not only related to its impact on its employees, but also on the region and community that are near the business location. In Saudi Arabia, the existence of business and production facilities is synonymous with employment for many people, as well as a valuable contribution to the economic development of nearby regions. In several developing countries, such as Saudi Arabia [67] and China [68], the application of eco-innovation and green manufacturing has shown to have an important impact in improving business social and environmental performances. Unfortunately, in Saudi Arabia, data about green implementation are still scarce, and according to the results obtained by the conducted survey, Saudi employees do not share the opinion that green practices can have a positive impact on social performance.

5.4.3. Testing the Impact of Implementation of Lean-Green Practices

The perception of Saudi employees regarding the combination of lean and green practices has been analysed based on the responses to the questionnaires. Saudi employees agree that, in order to implement such a complex combination, companies should design a well-planned strategy to improve processes at institutional and individual levels. In this chapter, a complementary quantitative analysis of the impact of the lean-green approach in the companies' performance from the employees' point of view is conducted. The main aim of this quantitative analysis is to quantify to what extent employees understand the need for combining lean and green practices, whether they think the implementation of such a combination is feasible within the Saudi manufacturing context, which barriers

they perceive, and which benefits they expect to achieve. This is performed by testing the hypotheses (H3a, H3b and H3c).

> **H3a:** *Lean practices moderate the relationship between green practices and operational performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.*

To test Hypothesis H3a, a Chi square test is used to compare the proportion of positive answers regarding green practices influencing operational performance with the proportion of positive responses regarding the combined lean-green approach influencing operational performance. The obtained results are shown in Table 14. In this case, the null hypothesis for the Chi-square test states that the proportions are equal in both groups (green and lean-green). The alternative hypothesis states that there are significant differences in the proportions of positive and negative responses between the two groups. Finally, a p value lower than 0.05 is considered to be statistically significant to reject the null hypothesis.

Table 14. Chi-square test comparing the proportion of agreement of respondents regarding lean-green approach towards operational performance and green approach towards operational performance.

		Lean-Green Approach towards Operational Performance		Total
		Yes	No	
Green approach towards Operational Performance	**Yes**	63	5	68
	No	22	12	34
Total		85	16	102

Pearson Chi-Square tests. Sig. = 0.045/degrees of freedom = 1/test statistic = 48.282.

From Table 14, it is possible to see that the proportion of positive responses evaluating the lean-green approach influencing the operational performance is higher than the proportion corresponding to the green approach influencing the operational performance (83% vs. 66%). This difference is statistically significant since a $p < 0.05$ was obtained. Then, hypothesis H3a is confirmed, meaning that lean practices actually moderate the relationship between green practices and the operational performance in such a way that the positive impact of green practices on the operational performance is stronger when lean practices are implemented.

Finally, to the best of the researchers' knowledge, the fact that green practices implemented concomitantly with lean practices are more likely to have a positive effect on the operational performance has previously been suggested by Sezen and Cankaya [11]. The analysis of the responses indicates that employees agree that green practices tend to complexify the production process. Implementing green practices in combination with some lean practices that are especially focused on improving operational aspects of the companies optimising their production processes, such as cell manufacturing, TPM, and quality at the source, can mitigate the adverse effects of the green practices and improve the operational aspects with respect to the implementation of the green practices individually. In addition, lean practices that are focused on the workplace organisation, such as 5S and visual management, can improve employees' working environment and simplify their everyday assignments, giving them more freedom and time to take care of additional tasks implied by the implementation of green practices. In this way, the implementation of green practices in a lean environment which makes processes more efficient and improves the organisation of the workplace can favour the implementation of the green practices without losing operational efficiency.

Both the results presented by Duarte and Cruz-Machado [69] as well as the ones obtained by the conducted survey are promising results towards making companies aware of the importance of combining both manufacturing practices, as well as towards encouraging them to practically implement such combinations.

H3b: *Lean practices moderate the relationship between green practices and environmental performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.*

To test Hypothesis H3b, a Chi square test is used to compare the proportion of positive answers regarding green practices influencing environmental performance with the proportion of positive responses regarding the combined lean-green approach influencing environmental performance. The obtained results are shown in Table 15.

Table 15. Chi-square test comparing the proportion of agreement in respondents regarding the lean-green approach towards environmental performance and the green approach towards environmental performance.

		Lean-Green Approach towards Environmental Performance		Total
		Yes	No	
Lean–greenapproach towards Environmental Performance	Yes	55	10	65
	No	27	10	37
Total		85	20	102

Pearson Chi-Square tests. Sig. = 0.001/degrees of freedom = 1/test statistic = 23.182.

It is obvious that the proportion of positive responses evaluating the lean-green approach influencing environmental performance (n = 82, 80.4%) is higher than the proportion corresponding to the green approach influencing environmental performance (n = 65, 63.7%). This difference is statistically significant since a $p < 0.05$ was obtained. Then, hypothesis H3b is true, meaning that lean practices actually moderate the relationship between green practices and environmental performance in such a way that the positive impact of green practices on environmental performance is stronger when lean practices are implemented.

Here, as in the case of hypothesis H3a, a synergetic effect of green and lean practices is demonstrated. In this case, this synergy occurs when evaluating the positive influence of lean-green practices on environmental aspects. In this way, the results obtained by the conducted survey suggest that intermediate and top-level managers should be aware that concomitant implementations are more likely to benefit business performance than any individual implementation.

H3c: *Lean practices moderate the relationship between green practices and social performance in such a way that the positive impact of green practices on operational performance is stronger when lean practices are implemented.*

To test Hypothesis H3c, a Chi square test is used to compare the proportion of positive answers regarding green practices influencing environmental performance with the proportion of positive responses regarding the combined lean-green approach influencing environmental performance. The obtained results are shown in Table 16.

Table 16. Chi-square test comparing the proportion of agreement in respondents regarding lean-green approach towards social performance and green approach towards social performance.

		Lean-Green Approach towards Social Performance		Total
		Yes	No	
Lean-green approach towards Social Performance	Yes	7	34	41
	No	8	53	61
Total		15	87	102

Pearson Chi-Square tests. Sig. = 0.580/degrees of freedom = 1/test statistic = 38.470.

From Table 16, it is possible to see that the proportion of positive responses evaluating the lean-green approach influencing social performance (n = 15, 14.7%) is lower than the proportion corresponding to the green approach influencing social performance (n = 41, 40.2%). This difference is not statistically significant since a $p > 0.05$ was obtained. Then, hypothesis H3c is false, meaning that lean practices are not able to moderate the relationship between green practices and social performance in such a way that the positive impact of green practices on social performance could be stronger when lean practices are implemented.

Contrastingly to the previous findings of the conducted survey regarding H3a and H3b, the results obtained in this case show that the achieved results by lean and green concomitant implementations in terms of social performance are not better than the ones obtained when implementing green practices individually. This reflects the current uncertain Saudi situation regarding social aspects of businesses. These social aspects are still an open question in Saudi Arabia, which as a developing country, still has a long way to go towards implementing better and safer business strategies, further focussing on business social responsibility [67,69].

5.4.4. Testing the Impact of Operational Performance, Environmental Performance and Social Performance towards Financial Performance

According to the proposed theoretical framework depicted in Figure 2, operational, environmental and social performances contribute towards the final financial performance of the company through Hypotheses H4, H5 and H6, respectively. In this section, these hypotheses are tested based on the analysis of the responses to the questionnaire, aiming to investigate how the improvements on operational, environmental and social performance obtained by the implementation of lean, green and lean-green approaches contribute to improve financial performance of the business.

H4: *Operational performance is positively related to financial performance.*

The results of the one-sample binomial test, shown in Figure 11, are the same as in the cases of Hypotheses H1a, H1b, H2a and H2b. In this context, the same comments stand, arriving to the conclusion that hypothesis H4a is true.

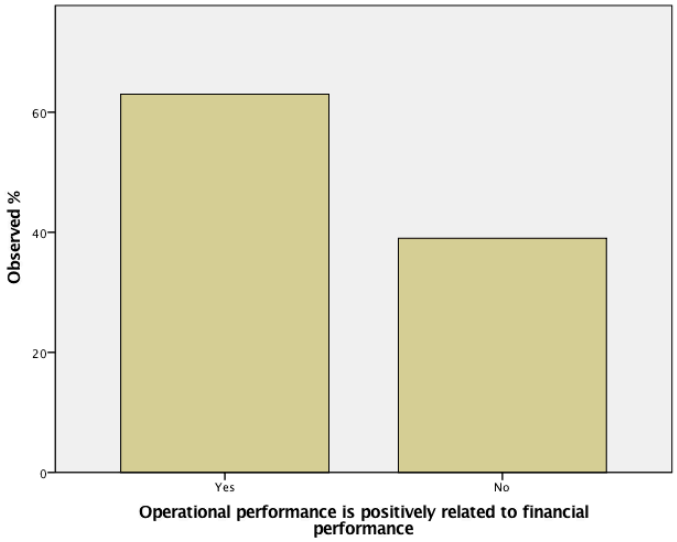

Figure 11. One-sample binomial test results for H4.

In general, operational performance is achieved by optimising production and supply chain in order to strictly fulfil business needs without surplus. Although most of the researchers in the field agree that the positive relation between operational and financial performances is natural and straightforward, even using these terms indistinctly, there are the ones, such as those that Khan and Al-Yafi [70] suggest, that increasing costs due to operational needs may lead to a decrease in financial performance. According to Protopappa-Sieke and Seifert [71],

optimising production may consume more time and resources, demanding for instance, increased transportation costs. Nevertheless, the situation pointed out in [71] tends to be the exception rather than the rule. Although optimisation of production and supply chain management can be more time and resource consuming, it is usually efficient regarding the total manufacturing costs, leading to improvements in financial performance. This is clearly reflected in the results obtained in the conducted survey, where the majority of respondents relate better operational performance with better financial performance.

The relationship between the operational performance and financial performance has largely been studied [72]. In general, improvements in the operational performance are achieved by optimising the different production processes and the supply chain management in order to strictly fulfil business needs without surplus. Although most of the researchers in the field agree that improvements in operational performance can lead to improvements in financial performance, there are those such as the ones in [71] that suggest that improving increasing costs due to operational needs may lead to a decrease in financial performance. Protopappa-Sieke and Seifert [71] argued that optimising production may consume more time and resources, demanding for instance increased transportation costs. According to the results obtained here, Saudi employees agree with most of the researchers in the field, supporting the idea that improvements in operational performance can lead to improvements in financial performance. These employees' perceptions can be explained as follows. Improvements in processes and equipment, such as the use of "error-proof" equipment, cycle time reduction, availability and reliability of machines, and use of cellular manufacturing, avoid incorrect processing and over-processing, whereas improvements in planning and control strategies, such as pull-flow control, overlapped production, visual control of the shop floor, small lot sizing, scheduling, levelled production, and inventory reduction contribute to reducing wastes in overproduction. In this way, the material, components and energy usage as well as the work in process and floor space utilisation are reduced, reducing the damaged products and the production costs without affecting the delivery time, making companies more competitive and profitable and improving the company's financial performance.

H5: *Environmental performance is positively related to economic performance.*

The results of the one-sample binomial test, shown in Figure 12, are the same as in the cases of Hypotheses H1a, H1b, H2a, H2b, and H4. In this context, the same comments stand, arriving at the conclusion that hypothesis H5 is confirmed.

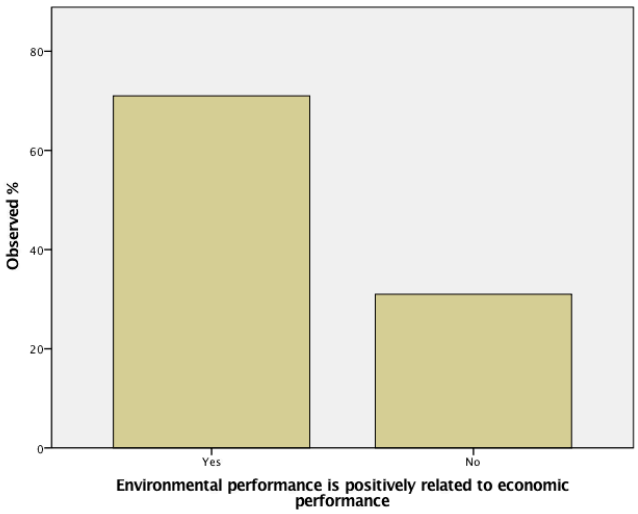

Figure 12. One-sample binomial test results for H5.

Improving environmental performance can be costly for business, usually requiring a high investment in new equipment, new working mythologies and processes, as well as specific training for employees. All these costs must be evaluated, and the ROI for each

one of them should be pondered before implementation. Many Saudi companies, which need raw materials for production, are reluctant to move to greener solutions, arguing either that there is not much more they can do to improve their environmental performance, or that the cost of a new investment is too high for the potential ROI they could achieve. The results obtained by the conducted survey show that, fortunately, Saudi employees' environmental concern is slightly changing. In this regard, it can be said that although Saudi top managers are still evaluating the potential ROI, they could be achieved if new processes aiming to achieve better environmental performance are implemented, Saudi employees are more confident regarding the financial potential of improving environmental performance. This can encourage Saudi top managers to implement greener solutions based on their employees' willingness towards doing so. In this promising context, a question still would remain regarding whether business is likely to change because of real environmental concerns or because of social (workers) pressure.

H6: *Social performance is positively related to economic performance.*

The results of the one-sample binomial test, shown in Figure 13, are the same as in the cases of Hypotheses H1c, H2c and H3c. In this context, the same comments stand, arriving to the conclusion that Hypothesis H6 is rejected.

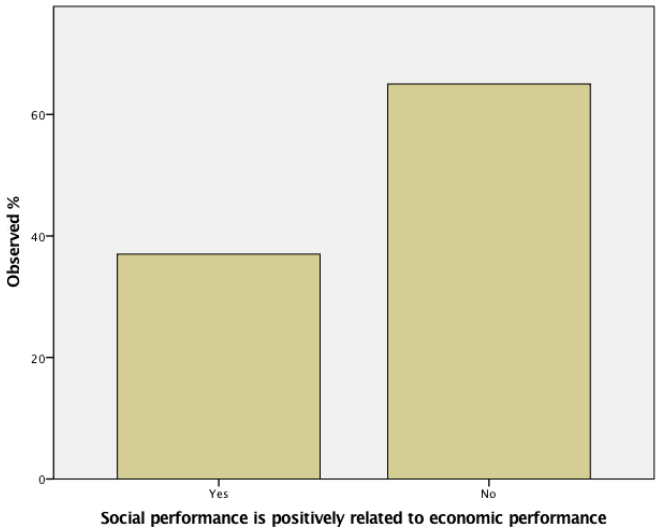

Figure 13. One sample binomial test results for H6.

Based on the results for the cases of Hypotheses H1c, H2c and H3c, testing the influence in social performance of lean, green and lean-green practices, respectively, social performance is not expected to have a positive impact on financial performance, as the results analysed in this section confirm. Governments, agencies and even some businesses from many developed countries have tried to pass the message that social performance is positively related to economic performance. Nevertheless, clear, unbiased and strong positive associations have not been widely reported, suggesting that not all businesses are likely to benefit from improved social performance. A study by Protopappa-Sieke and Seifert [72] has previously deconstructed this view by showing that corporate social responsibility has a neutral impact on financial performance. The findings of the conducted survey are in accordance with the observations by McWilliams and Siegel [73], suggesting that social performance has no positive impact on the financial performance of Saudi businesses. Surveyed employees have pointed out social aspects as one of the more critical issues that Saudi companies should solve. In particular, they have suggested social improvements at institutional and individual levels. On one hand, these changes can lead to benefits since they will improve worker conditions, which will benefit the company by having motivated and well-trained employees, and will improve the company's image, which will increase its sales. On the other hand, these changes require a high investment

with no ROI in the short term. This is probably the reason why employees that do not perceive improvements in social performance can translate improvements in financial performance.

6. Conclusions

In order for the integration of lean, green and lean-green approaches to be possible in the context of Saudi manufacturing SMEs, a survey was conducted in different Saudi companies focused on different business areas. The proposed hypotheses supporting the theoretical framework proposed in the paper were tested within the Saudi companies' context based on the quantitative analysis presented.

Based on the statistical analysis of the collected data conducted, promising results have been obtained, showing that, in general, Saudi practitioners are starting to change their perception about lean and green approaches implementation, being more aware of their benefits regarding some of the main aspects of sustainability, in particular, operational and environmental ones. Moreover, the conducted statistical tests showed that the combined lean-green approach can have a higher positive impact on operational and environmental performances than the one corresponding to the green practices being implemented individually. In this way, most of the hypotheses (8 out of 12) supporting the theoretical manufacturing framework proposed, in particular, the ones regarding the operational and environmental performances (H1a, H1b, H2a, H2b, H3a and H3b), have been validated.

Finally, the presented results in this paper not only make a valuable contribution to the literature of lean, green and lean-green manufacturing in general and to the Saudi one in particular, but they also provide useful benchmark results that can be used as the starting point towards more standardise lean-green practices, leading to more comparable sustainable performance.

Some limitations of this research are inherent to the chosen methodological strategy. In this regard, although survey studies are useful tools for collecting data, they have some limitations. In general, surveys tend to oversimplify the reality by relying on questionnaires with a limited number of questions. Moreover, the cross-sectional nature of the conducted survey in this thesis also contributes to the oversimplification tendency. In addition, Likert scale questions based on pre-conceived categories represent a bias. In this thesis, the data obtained using Likert scale questions were complemented with the data obtained by textual questions, which allow participants to freely answer them, providing more detailed information. Nevertheless, although giving survey participants the freedom to answer the questions is intended to obtain more detailed, descriptive and unbiased answers, the quality of the obtained answers highly depends on the participants' engagement with the survey process. Even when questions are well-formulated and relevant to the research, and the validity of the survey has been tested in terms of its statistical significance, the validity of the collected data, the reliability of the obtained results, and their relevance to the field are highly dependent on the capability (and willingness) of the participants to properly and honestly answer the questions.

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