Measuring the Impact of Lean Manufacturing Practices on Sustainability Performance: A Proposed Model

Abstract:

Over the last years, the sharp competition among organizations forced them to reduce cost and to be more responsive to customer demands as well as improving the value provided to them. In addition, there has been increasing pressure on businesses to manage their operations responsibly in regards to their environmental and social impacts in addition to economic impacts. This has motivated companies and researchers to identify ways to response to customer demands and implement sustainable operations. Lean manufacturing and its practices is considered an important way to achieve this goal through its capability to waste elimination or reduction. Therefore, the main objective of this research is to propose a quantitative model that could be used to investigate whether lean manufacturing practices (tools) can improve the three aspects of corporate sustainability performance (economic, environmental and social). This work is considered an extension of previous studies by analyzing such interactions related to the triple bottom-line dimensions of sustainability in condition of lean practices implementation.

Introduction:

Recently, companies in developed countries have been facing increasingly sharp competition. In this context, where customers have become more demanding and more versatile, lean manufacturing has been widely adopted. It leads to achieve numerous benefits such as waste reduction, value improvement, making products with fewer defects, customer focus (high quality, low cost, short time), and cost reduction (Pettersen, 2009).

More recently, environmental and social concerns have increasingly become critical issues within our societies and economies as well as the economic concerns. Since the end of the Eighties, the common sustainable development concept defined as "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987). A sustainable enterprise is the one that contributes to sustainable development by simultaneously delivering economic, social, and environmental benefits or what has been termed "the triple bottom line" (Norman and MacDonald, 2004). Many authors (Thanki et al., 2016; Cherrafi et al., 2016; Chiarini, 2014b; Faulkner and Badurdeen, 2014; Pampanelli et al., 2014; Martinez-Jurado and Moyano-Fuentes, 2014; Ng et al., 2015) claim that lean production seems to has significant effects on the reduction of

environmental impacts such as emissions into the air, water and soil, as well as efficiency of water and energy consumption. In fact, every time a Lean tool or principle is applied, there are also benefits concerning environmental management. However, it is not clear exactly what kind of relationship exists between a specific Lean tool and the environmental impacts and whether or not this relationship can be measured. One of the most important tools or techniques of lean manufacturing that has a vital impact on the sustainability performance is The Value Stream Mapping (VSM). VSM technique has efficiently accomplished the integration of both production and environmental goals in one management approach for the manufacturing industry (EPA 2007). VSM is a lean technique that was originally applied in manufacturing to deal with production problems. Then, VSM was adapted to manage environmental problems in manufacturing using a green approach (EPA 2007). Therefore, it is argued that the VSM provides a green-lean approach for managing the production systems, simultaneously accomplishing both production and environmental goals (Helleno et al., 2016).

The next section of this study include the literature review to assess the current knowledge about lean manufacturing and sustainability performance to identify the research gap, then, a proposed model of the study has been presented, finally, research limitation and future research have been suggested.

Theoretical Background

- **Lean manufacturing:**

Lean concept has been widely accepted in the service and manufacturing industries (Abdul Wahab et al., 2013). The term lean production was first used by Womack et al. (1991) to describe the Toyota production system (TPS). Despite there is a number of previous studies related to lean manufacturing concept, there is no uniform definition of that concept. Some definitions focused on the principles and practices of lean manufacturing (Womack and Jones, 2003; Vinodh et al., 2011; Sundar et al., 2014; Sharma et al., 2016), Some other definitions focused on the main objectives of its implementation (Cherrafi et al., 2016; Aguado et al., 2013; Abdul Wahab et al., 2013; Fercoq et al., 2016), While others attempted to make a link between the practices of lean manufacturing and the objectives of its implementation (Anvari et al., 2010; Martínez Leon and Calvo-Amodio, 2017). Womack and Jones (2003) stated that lean manufacturing include five general principles: defining the value from customer perspective, mapping the value stream process to achieve the predefined value, creating the

flow along the value chain, establishing pull system and pursuing perfection. Abdul Wahab et al. (2013) and Fercoq et al. (2016) focused on the main goal of implementing lean production in an operation to eliminate or reduce or manage waste to increase productivity, enhance quality, shorten lead times, and reduce cost. Therefore, it may be considered that the best definition of lean manufacturing system is that make a combination between lean practices and the main goal of its implementation, as a manufacturing system that includes a set of principles/practices (tools/techniques) to identify and remove all forms of waste within all the processes and activities of the firm, hence reducing the cost, improving product quality and maximizing customer value (Martínez Leon and Calvo-Amodio, 2017).

Although Womack and Jones (2003) stated that lean principles can be applied in any industry, few organizations attain significant improvements by applying lean. Baker (2002) reported that the success percentage of UK organizations on lean implementation is less than 10%. It is believed that the main reason of not getting the lean benefits is the incomplete understanding of the lean concept and the purpose of the lean practices. This misunderstanding strongly restricts the lean implementation process and reduces the expected benefits for the organization (Mostafa et al., 2013).

- **Lean manufacturing practices (tools):**

Lean practices **(**tools) represent the lean principles in an implementation form. There are many tools (techniques) of lean manufacturing, the number of them vary from study to other. The most common practices in previous studies are the following:

Table 1: The common practices of lean manufacturing and their meaning (**Source**: Sharma et al., 2016; Chiarini, 2014b; Sundar et al., 2014):

Lean practices	The meaning
Value stream mapping (VSM)	The process of mapping the material and information flows required to coordinate the activities performed by manufacturers, suppliers and distributors to deliver products to customers.
Cellular Manufacturing	The grouping of miscellaneous equipments to produce the family of parts. VSM provide route map for every homogeneous parts of products, based on the route map the different machines are grouped together to form a cell. This is called group technology in lean.
Continuous Improvement (CI) /Kaizen	Design and implement a process with zero inventories to overcome the waste such as the idle time, waiting time, inventory and resource problem. In order to eliminate this waste, management need to develop the personnel

	with organization knowledge base. CI depends on employee perception, adaptation, team work, leader engagement, motivation and training.
5 S	A technique that include five steps for a well-organized workplace: separating, setting in order, shining and cleaning up, standardizing and sustaining the workplace. A well-organized workplace results in a safer, more efficient, and more productive operation. It ensures continuous improvement in housekeeping and results in better environment and safety standards.
Total Productive Maintenance (TPM)	A technique that make the machines and equipments maintenance before the actual occurrence of breakdown, hence, reducing failures of it.
Just in time (JIT) / Pull system	A system where the production or movement of inventory items is initiated as required by the using department or the customer. The basic feature is that production and distribution are demand driven, zero inventory or minimum inventory is maintained and response is made to specific orders.
Single minute exchange of die (SMED)	A technique for performing setup operations in a number of minutes expressed in a single digit. It enables an organization to quickly convert a machine or process to produce a different product. By applying the SMED the set up times would be reduced to few minutes or even seconds in many cases thus improving productivity.
Visual Control	A technique employed in many places and contexts whereby control of an activity or process needs to be made easier or more effective by a planned use of visual signals.
Total Quality Management (TQM):	A comprehensive and structured approach to organizational management that seeks to improve the quality of products and services through ongoing refinements in response to continuous feedback. It based on quality management from the customer's point of view.
Six Sigma	An organized structure to reduce variation in organizational processes. It includes performance metrics with the aim of achieving strategic objectives. The Six Sigma problem solving structure includes five phases called the DMAIC cycle (Define, Measure, Analyze, Improve, and Control).
Error Proofing / Poka-yoke	A poka-yoke device is any mechanism that either prevents a mistake from being made or makes the mistake obvious at a glance.

Sustainability performance:

The concept of sustainable development first evolved in 1972 at the UN Conference on the Human Environment held in Stockholm (Rogers et al., 2008). There are several definitions of sustainable development, but the most well known definition of it is that of the World Commission on Environment and Development (1987): "economic development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs" (Nations, 1987). In the manufacturing sectors, sustainability aims to create manufactured products which use processes and practices that maximize profits, minimize negative environmental impacts, conserve natural resources and energy, and are safe for employees, consumers, and communities (Martínez Leon and Calvo-Amodio, 2017). Thus, sustainability performance includes three interrelationship dimensions: economic (profit), environmental (planet), social (people) (Rezaee, 2016).

Literature Review:

The literature related to lean manufacturing and sustainability performance can be categorized into three groups, Studies discussed the relationship between lean manufacturing and economic (financial / operational) performance. Other studies of the investigated the relationship between lean manufacturing and environmental performance. While other studies emphasized the relationship between lean manufacturing and social performance.

Regarding the relationship between lean practices and economic (financial/ operational) performance (the first group), the objective of Fullerton et al. (2014) was to propose approach for implementation of lean management accounting practices (LMAP) rather than traditional management accounting practices (TMAP) to meet the demands and objectives of lean organizations. They cleared that TMAP focus on minimizing average product cost. Thus, TMAP lead operations managers to make decisions that are inconsistent with lean objectives. In contrast, the financial control provided by LMAP is simpler and easier to understand. LMAP help operations managers to make decisions that reduce inventory and better utilize capacity, inrease their focus to maximizing customer value and the efficiency of the value stream, and motivate them to strive for continuous improvement. The study used survey data from 244 U.S. manufacturing firms and analyzed data using structural equation model. The most significant result of the study is that the extent of lean manufacturing implementation is associated with the use of LMAP. Then, the extent of lean manufacturing practices is directly related to operations performance. Lean manufacturing practices also indirectly affect operations performance through LMAP.

Using data provided by 121 U.S. manufacturing executives, Fullerton and Wempe (2009) examined how use of non-financial manufacturing performance (NFMP) measures affect the relationship between lean manufacturing and financial performance. A structural equation model (SEM) is estimated. The results provided evidence that utilization of NFMP measures mediates the relationship between lean manufacturing and financial performance (profitability). Results of the study also confirm that lean production methods encourage the use of NFMP measures. Utilization of NFMP measures of lean practices that related to setup time reduction, cellular manufacturing, and quality improvement initiatives have direct effects on profitability.

Hofer et al. (2012) also empirically investigated the relationship between lean production implementation and financial performance, emphasizing on the mediating role of inventory leanness in deriving the financial performance benefits commonly associated with lean production. Based on an analysis of a combination of survey and secondary data, the effect of lean production on financial performance was partially mediated by inventory leanness. In addition, there was strong evidence that the concurrent implementation of internally-focused and externally-focused lean practices has been showed greater performance benefits than selective lean production implementation. Using Survey of 711 firms for various industries from 23 countries, and collecting data during 2005 – 2006, Demeter and Matyusz, (2011) found that firms that implement lean practices have higher inventory turnover and financial performance than firms did not implement these practices.

Yousef et al. (2015) aimed to measure the potential operational and financial improvements of implementing lean manufacturing using lean accounting tools. Using a case study in Egypt on the cement factory of Misr Cement Co., they developed lean accounting tools (Value Stream Cost (VSC), and Box Scores) to measure the overall potential benefits of lean improvements. The results showed potential improvements in the flow of production due to elimination of the waste and the bottlenecks, hence, increasing the speed of response to the customers and decreasing the product cycle time. There were also potential improvements in the product quality due to the elimination of recycling and defects. This result is similar to the result of Meade et al. (2010) that they opposed standard cost systems and supported lean production implementation concerning with its impact on reported profits of the firm.

Biscontri and Park, (2000) aimed to investigate the effects of lean production on earnings. Using telephone interview with manufacturing, purchasing, or quality assurance manager of 93 firms adopted lean production during 1989 to 1994 and a control sample of 93 non adopted

firms. The result showed that there were contrasting effects (both positive and negative) of lean production on earnings. The improved operating performance through productivity improvement, reduction in non-value-added activities, better manufacturing flexibility, better plant utilization, and improved quality of product and process, hence it contributed to operating profit increase. On the contrast, increased raw material and new training costs, big initial investment in JIT caused income reduction for lean firms. However, the study pointed to that in the long run, expected cost savings from the reduction in inventory, storage space, overhead costs, personnel, waste, and inefficiency would all contribute to the improvement of financial performance.

Harris and Cassidy, (2014) aimed to investigate whether lean companies experienced better profitability performance related to various financial-performance measures than non-lean companies. Using secondary (archival) data about three profitability measures and three cash-flows measures for each of compared companies for three fiscal years of data: 2008, 2009, and 2010. The results showed that lean companies had greater returns on net operating assets (RNOA), returns on total assets (ROA), operating cash flows, and cash adequacy ratios than Non-Lean companies. These results were driven by the larger lean companies. The profit margins ratios also were relatively better for the lean companies than the non-lean companies.

After reviewing previous literature regarding the relationship between lean manufacturing practices and economic (financial/ operational) performance (first group), it could be noticed that most of these studies were applied to manufacturing industry (Fullerton and Wempe, 2009; Demeter and Matyusz, 2011; Fullerton et al., 2014; Harris and Cassidy, 2014; Yousef et al., 2015). Also, there is diversity in the implementation environment, such as Egypt (Yousef et al., 2015), USA (Fullerton and Wempe, 2009; Fullerton et al., 2014), many countries (Demeter and Matyusz, 2011). Regarding data collection, some studies relied on primary data via a questionnaire (Demeter and Matyusz, 2011; Fullerton et al., 2014), telephone interviews (Biscontri and Park, 2000), or both a questionnaire and interviews (Yousef et al., 2015). Some other studies relied on secondary data extracted from internal reports or published financial reports (Harris and Cassidy, 2014). While other studies relied on a combination of survey and secondary data (Hofer et al., 2012). Regarding the results of these studies, some studies found a positive direct effect of lean manufacturing practices implementation on the operational and financial performance (Harris and Cassidy, 2014). While some other studies found a positive indirect effect of lean manufacturing practices implementation on the financial performance through nonfinancial performance measures (Fullerton and Wempe,

2009; Demeter and Matyusz, 2011; Hofer et al., 2012; Yousef et al., 2015). One study found contrasting effect (positive and negative) of that relationship (Biscontri and Park, 2000).

So, it is clear that this group of studies tried to determine the relationship between lean manufacturing practices implementation and the economic sustainability performance, but the results of these studies were different. Also, there are no studies in Egypt to determine this relationship, that its results could be statistically generalized (except a study of Yousef et al. (2015), that relied on a case study).

With regard to studies that addressed the relationship between lean practices and corporate environmental performance**,** environmental considerations have led organizations to take an important role in designing environment friendly, recyclable products to complement improvements in the environmental standards of products. In this context, many previous studies found that the application of lean practices may result in environmental benefits such as pollution reduction.

Many authers, (Cheah et al., 2013; Van Hoof and Lyon, 2013; Bracci and Maran, 2013; Chiarini, 2014a) suggested new strategies and tools to improve environmental performance, such as ISO 14001 certification, Life-Cycle Assessment (LCA), waste management, reuse and reproduction. However, those authers did not directly suggest the implementation of lean production or of its tools and principles.

On the other hand, some authers (Fercoq et al., 2016; Cherrafi et al., 2016; Chiarini, 2014b; Faulkner and Badurdeen, 2014; Pampanelli et al., 2014; Martínez-Jurado and Moyano-Fuentes, 2014; Ng et al., 2015) suggested that lean production seems to have significant effects on the reduction of environmental impacts such as emissions into the air, water and soil, as well as efficiency of water and energy consumption.

King and Lenox (2001) demonstrated that lean production can reduce the costs of pollution. In particular, it is complementary to waste and pollution reduction. Their study based on a quantitative inquiry carried out through a sample of US companies from 1991 to 1996. The study results validated its hypotheses which correlated the lean production efforts of a company to its environmental management practices.

Chiarini (2014b) empirically observed five European companies that manufacture motorcycle components and which are also committed to lean and environmental management. The environmental impacts of the production processes of the five companies were observed and measured before and after the implementation of five Lean tools: Value Stream Mapping (VSM), 5S, Cellular Manufacturing, Single Minute Exchange of Die

(SMED) and Total Productive Maintenance (TPM). The Comparison of the before and after quantitative results revealed that: VSM, In particular, can be used to identify the environmental impacts of production processes. 5S can be useful for reducing oil leakage and improving waste management. Cellular manufacturing can lead to a decrease in electricity consumption. Whereas TPM can help to reduce several impacts of the machines, such as oil leakage and emissions of dusts and chemical fumes into the atmosphere. In contrast, no significant improvement in environmental impacts was achieved after implementation of SMED. The EPA (2003) discussed a correlation between the seven lean wastes and the environmental impacts they can create as shown in table 2.

Table 2: Environmental impacts linked with type of manufacturing waste (source: EPA, 2003).

Waste type	Environmental impact
Defects	Raw materials consumed in making defective products. • Defective components require recycling or disposal. • More space required for rework and repair, increasing energy use for heating, cooling, and lighting.
Waiting	• Potential material spoilage or component damage causing waste. • Wasted energy from heating, cooling, and lighting during production downtime.
Overproduction	More raw materials consumed in making the unneeded Products. Extra products may spoil or become obsolete requiring disposal.
Movement and transportation	• More energy use for product transportation. • Emissions from transportation. • More space required for work-in-process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption. More packaging required to protect components during movement.
Inventory	• More packaging to store WIP. • Waste from damage to stored WIP. • More materials needed to replace damaged WIP. • More energy used to heat, cool, and light inventory space.
Complexity and over processing	More parts and raw materials consumed per unit of production. Unnecessary processing increases wastes, energy use, and emissions

Unused creativity	Fewer suggestions of pollution and waste minimization opportunities.

Faulkner and Badurdeen (2014) focused at the environmental impacts of one of the important tools of lean production called Sustainable Value Stream Mapping (SVSM). SVSM represent an extension to conventional VSM through adding energy-related metrics to Value Stream Maps. The study aimed to present a comprehensive methodology to develop SVSM by identifying suitable metrics and methods to visually present it. The SVSM methodology was validated through a case study of a local manufacturer of television satellite dishes. The most significant result of the study was that the proposed methodology of SVSM is considered an effective in visually evaluation of production lines sustainability performance.

Also, Pampanelli et al. (2014) proposed a new model, which they called the Lean and Green Model that made an integration of environmental sustainability into lean thinking. The model used a Kaizen approach to improve energy flows in lean manufacturing environments. The model was designed for, and was limited to, the cell level, which is the first stream level of a manufacturing business that supports the principles of lean thinking model. The model was validated using a case study of a major global engineering company that services the automotive and aerospace industries in Brazil in 2011. The important finding of their study was that, this model increased the productivity as it could reduce resources use from 30 to 50% on average and had the potential to reduce the total cost of energy flows in a cell by 5 - 10%. Also, the model reduced environmental impact of the production processes.

In the same context, (Cherrafi et al., 2016; Chiarini, 2014b; Vinodh et al, 2011) stated some lean principles / tools and sustainable benefits of each one. This is cleared as shown in table 2.

Tabel 2: Environmental benefits of lean principles (Source: Cherrafi et al., 2016; Chiarini, 2014b; Vinodh et al, 2011)

Lean principle/tool	**Sustainable benefits**
Pull approach / Just in time	Reduction of work-in-process, elimination of potential waste from damaged products, less floor space utilization.
Cellular manufacturing	Reduction in set-up times and changes over time, so low energy and resource usage, reduction in defects.

Value Stream Mapping	Reduction in waste through fewer defects, less scraps, low energy usage, etc.
5S	Reduction in lighting requirements due to clean windows, reduced consumption of materials and chemicals.
Total preventive maintenance	Less hazardous waste due to decreased spills and leaks, increased life of equipment.
Six sigma	Fewer defects, less waste, improvement in product durability and reliability, increase in product lifespan.
Pre-Production planning	Reduction of waste at design stage, usage of right sized equipments, reducing the complexities of production processes and product design.
Kaizen	Elimination of hidden wastes and unnecessary activities.
Visual controls	Identification and elimination of unnecessary departments, so less material usage and wastes.
Lean supplier networks	Introduction of lean to existing suppliers would lead to better realization of environmental benefits.
PoKa YoKe	Reduction in defects, so less waste, low energy usage, less scrap.

In the same direction, Ng et al. (2015) proposed an approach that integrated metrics derived from Lean and Green implementation in one metric called "Carbon-Value Efficiency". Using a case study of metal stamped parts production, the results showed that Carbon-Value Efficiency can be improved by 36.3%, given an improvement in production lead time by 64.7% and a reduction in carbon footprint by 29.9%.

Also, Thanki et al. (2016) applied an analytical hierarchy process approach to investigate the impact of selective lean (TPM, Kaizen and 5S) and green practices (ISO 14001, 3R and DFE) on overall performance of Indian SMEs. Data were collected through a questionnaire to a sample of eleven industrial experts and one academic expert in some Indian SMEs. The results concluded that total productive maintenance (TPM) was identified as the most important lean practice, while ISO 14001 was the most significant green practice. Also, On-time delivery/ quality control were the most critical criteria for leanness and a reduction in emissions / energy consumption were the most critical criteria for greenness.

Reviewing previous studies that examined the relationship between lean practices and corporate environmental performance highlights some relevant conclusions. Some of these

studies addressed the relationship between one or some of the lean practices and the environmental performance (Faulkner and Badurdeen, 2014; Thanki et al., 2016). While other studies addressed the relationship between lean production as a whole (all practices) and environmental performance (King and Lenox, 2001; Vinodh et al, 2011; Chiarini, 2014b; Pampanelli et al., 2014; Ng et al., 2015; Cherrafi et al., 2016; Thanki et al., 2016). These studies were applied to different business environments. Among these environments are: USA (King and Lenox 2001), Europe (Chiarini, 2014b), India (Thanki et al., 2016), Brazil (Pampanelli et al., 2014). Wide range of research methodologies and data collection techniques were applied. Some studies relied on the questionnaire in collecting the data through survey (King and Lenox, 2001; Thanki et al., 2016). Most studies collected data using questionnaire or interviews through case studies (Chiarini, 2014b; Pampanelli et al., 2014; Faulkner and Badurdeen, 2014; Ng et al., 2015). Regarding the results of this studies, some studies pointed out that there is a positive relationship between lean manufacturing practices as a whole and the improvements in the environmental performance (Faulkner and Badurdeen, 2014; Pampanelli et al., 2014; Ng et al., 2015; Thanki et al., 2016). While other studies concluded that there is a positive relationship between only one or some of the lean manufacturing practices, but there is no relationship for other lean practices (Chiarini, 2014b).

So, it is clear that these studies (second group) tried to determine the relationship between lean manufacturing practices implementation and the environmental sustainability performance. However there is a research gap at these studies, that every time a lean tool or principle was applied, there were environmental benefits. However, it was not clear exactly what kind of relationship exists between a specific lean tool and the environmental impacts and whether or not this relationship can be measured. Another gap in these studies is there was no studies addressed this relationship in Egypt.

With regard to studies that addressed the relationship between lean practices and corporate social performance (third group). Previous studies pointed out that sustainability ensures not only that industries are achieving profits, but also that industrial activities do not cause social damage. Social performance refers to the actual improving and maintaining of the human life quality without neglecting environmental aspects (Helleno et al., 2016). This ensures that also environmental initiatives lead to better working conditions, which in turn increase the motivation and productivity of the workers.

Gunarathne et al. (2016) aimed to identify the usefulness of safety controls and accounting in corporate social sustainability management in response to various stakeholders' demands and

expectations in the mining sector in Sri Lanka. The case study approach was followed in this study. Data collection was mainly based on semi-structured interviews, on-site assessments and documentation reviews. The most important result of this study was that the health and safety of employees and the quality of their working conditions were the most important of studied aspects.

Previous studies addressed the aspects or indicators of social performance related to lean production, for example, Bonavía and Marín-Garcia (2011) aimed to analyze the effect of lean production on the policy of human resource management. Also it aimed to determine whether or not lean production related human resources practices explains the difference in organizational performance. Based on a questionnaire and data collection from 76 establishments that specialize in single-firing ceramic tiles in Spain. The study concluded that companies that implement most of lean production practices are also those that take care to train workers in using these practices as well as improving their employment security. Also, the combination of lean production and human resources practices reduces inventory and increase productivity.

In the same direction, Uhrin et al. (2017) aimed to investigate the role played by workforce development in the relationship between the degree of implementation of lean production and operational performance. Data were collected via questionnaire. It was sent to 84 manufacturing plant of 216 plants of Original Equipment Manufacturers in the Spanish automotive industry.

Wong and Wong (2014) aimed to propose a framework to address human integration in lean thinking for sustaining operations. Based on a case study of a multinational semiconductor manufacturing company in Malaysia. The study result concluded that people can be integrated through a scientific methodology in lean. Also, the synergies from the horizontal and vertical directions of human integration can lead to value creation in the organization.

On the other hand, Martinez-Jurado and Moyano-Fuentes (2014) relied on a theoretical study to evaluate the links between lean management, supply chain management and sustainability. It aimed to identify and classify the related literature that has been carried out and extended from an internal focus to an entire supply chain focus, and considering the three key dimensions of sustainability in order to determine the gaps that exist and draw conclusions to aspects that require further research. The study concluded that there is a significant research gap regarding social sustainability in lean supply chain management. So the key social performance metrics needed to be identified.

Reviewing previous studies that examined the relationship between lean practices and corporate social performance (third group) highlights some relevant conclusions: These studies were applied to different business environments. Among these environments are: Sri Lanka (Gunarathne et al., 2016), Spain (Bonavía and Marín-Garcia, 2011; Uhrin et al., 2017), Malaysia (Wong and Wong, 2014). Several data collection techniques were used, questionnaire (Bonavía and Marín-Garcia, 2011; Uhrin et al., 2017), interviews (Wong and Wong, 2014), and both on-site assessments and documentation reviews (Gunarathne et al., 2016). Regard of the results of this group of studies, these results has been different, most of these studies found direct positive relationship between lean practices implementation and human resource practices (social performance) (Bonavía and Marín-Garcia, 2011; Wong and Wong, 2014; Uhrin et al., 2017). Some other studies found that there is a positive indirect relationship between lean practices implementation and the social performance of sustainability through the environmental performance improvement. This means that, lean practices implementation support the environmental initiatives that lead to better working conditions, which in turn, increase the motivation and productivity of the workers (Helleno et al., 2016). There is a significant research gap regarding social sustainability in lean environment concerning supply chain management. So that key social performance metrics need to be identified (Martínez-Jurado and Moyano-Fuentes, 2014).

Another gap in these studies is there is no studies addressed this relationship in Egypt.

Last but not least, After the previous discussion of the three groups of the literature review, it is clear that in spite of the large number of studies that addressed the impact of lean practices implementation on one aspect of sustainability performance aspects (economic/ environmental/ social), there is a lack of studies that aims to investigate the effect of these practices on the sustainability performance as a whole (the three aspects). Also, most of analyzed studies have been focused on the environmental performance aspect, with less interest with other aspects (economic/ social). Another gap in these studies, that need more research and study is there is no studies addressed the impact of lean practices implementation on sustainability performance as a whole in Egypt as a developing country.

As a first step to study this relationship in Egypt and in light of previous studies, Figure 1 shows the research model that includes the main relationships of this study:

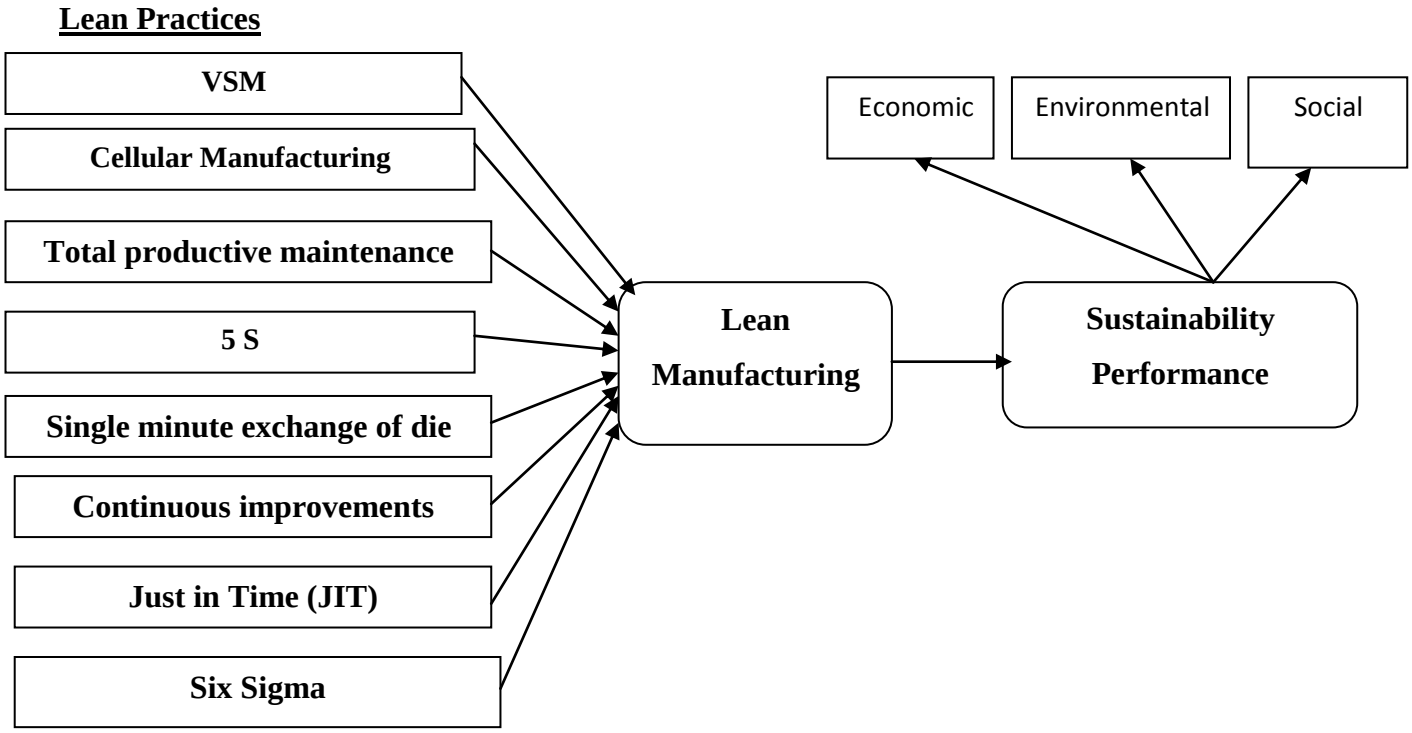

Figure 1: The Research Model

The suggested Model

In an attempt to fill the gap in the literature and depending on literature review and the measures used to measure sustainability performance variables, this paper suggests a quantitative model to measure sustainability performance in firms that implement lean manufacturing practice. The model is based on a set of financial and non-financial measures. The model is discussed as follow:

The research Model examines the relationship between lean practices and sustainability performance as a whole.

$$SP = \alpha + \beta LP + \varepsilon \qquad (1)$$

Where:

SP = the sum of economic performance, environmental performance and social performance.

LP = inventory turnover rate, Equipments and Machines setup duration.

Model (2) examines the relationship between lean practices and economic performance.

$$EcP = \alpha + \beta LP + \varepsilon \qquad (2)$$

Where:

EcP = return on net operating assets (RNOA), returns on total assets (ROA), inventory cost, productivity rate and customer response rate.

Model (3) examines the relationship between lean practices and environmental performance.

$$EnvP = \alpha + \beta LP + \varepsilon \qquad (3)$$

Where:

EnvP = resource consumption rate per unit, renewable raw material usage to total used raw material, waste of per produced unit, CO2 emission, and best benchmark of environmental management.

Model (4) examines the relationship between lean practices and social performance.

$$SocP = \alpha + \beta LP + \varepsilon \qquad (4)$$

Where:

SocP = Number of workforce work hours, rate of employee turnover (work absence days), rate of employee work environment safety, average employee training hours per year, extent of environmental and social consideration for supplier selection.

Concluding Remarks

Despite the growing importance of the sustainability performance in recent years, more research is needed to recognize and measure sustainability performance in firms that implement lean manufacturing practice.

Companies compete in markets with increased need to customers' response and maximizing value to them, and the same time the need to improve financial and operational performance of the firm within limited resources. This has forced companies to manage their operations responsibly through the implementation of sustainable practices. One of the most important ways to achieve this is the implementation of lean manufacturing practices.

This study provides a proposed quantitative model for measuring the effect of lean manufacturing practices implementation on the three aspects of sustainability performance (economic / environmental / social).

The proposed model has been built based on related previous studies, as well as its variables metrics and indicators. In the proposed model, most common lean manufacturing practices (tools) were: Value Stream Mapping (VSM), Cellular Manufacturing, Total Productive Maintenance (TPM), 5S, Single Minute Exchange of Die (SMED), Continuous Improvements (Kaizen), Just In Time (JIT) and Six Sigma. Sustainability performance consists of economic (financial / operational) performance, environmental performance and social performance. The model attempts to measure sustainability performance within lean

manufacturing firms based on the data that most of it is not publicly available. Data unavailability imposes measurement difficulties that may be considered as a research limitation.

The study provides a theoretical discussion designed to promote a more precise and inclusive measurement of sustainability performance within lean manufacturing firms. Further research is needed to empirically validate of this study. For example, by a cross-sectional study using a sample of Egyptian lean manufacturing firms or by an experimental study comparing sustainability performance of an experimental lean manufacturing firms with sustainability performance of control manufacturing firms do not implement lean practices. Thus, future researches are encouraged to apply the suggested model in different settings.

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