THE EFFECT OF APPLYING LEAN SIX SIGMA (LSS) ON WAREHOUSE WASTE LEVEL A CASE STUDY ON I.V.L DHUNSERI POLYESTER COMPANY S.A.E

Emad Elwy Habib*
October University for Modern Sciences and Arts (MSA), Egypt
Amr Gouda Hassanein**
Arab Academy for Science, Technology and Maritime Transport, Egypt

ABSTRACT

Lean six sigma (LSS) has been widely acknowledged throughout the last decade in the Industrial affaires. The research is conducted to understand the LSS application effect on the waste level reduction in the PET (Polyethylene Terephthalate) industry. The purpose of the study that will be used is to understand the effectiveness of Lean Six Sigma (LSS). The research paper encompasses both descriptive and empirical approaches. The application of this research only took into consideration the PET (Polyethylene Terephthalate) industry. Surveying dataset was the main source of the primary data in addition to the secondary data which was collected and obtained from I.V.L Dhunseri Polyester Company S.A.E as well. The data set consisted of 366 observations of time series data points for waste levels. The methodology used was exploratory factor analysis to reduce dimensions followed by the confirmatory factor analysis (CFA), structural equation modelling (SEM) and time series analysis combined with dummy ARIMA model. The descriptive analysis was via pie charts and computing the mean and standard deviation for Likert scaled statements. Also, for deeper insights the pareto analysis was used. It was noticed that there are problems that arise during the supply chain processes. One among the most reported problems are the unnecessary costs and the defects presence due to wastes and pushes a greater motive for companies like I.V.L Dhunseri Polyester Company S.A.E to consider LSS. The research realizes that there is a drastic increment throughout the efficiency and profit effectiveness. Due to large sample size the T paired test shall be used. In general, the waste level was different from before and after application of LSS. It was also found that, all the statements were reliable and valid when confirmatory factor analysis was applied. After modelling, a significant relationship between the application of LSS five processes and the level of waste reduction were found. A dummy ARIMA (1,1,2) was a good fit for data. The application of LSS was found out to have a significant negative effect on the waste level.

Keywords: *Lean six sigma (LSS), warehouses management, waste management, I.V.L Dhunseri Polyester Company S.A.E, PET (Polyethylene Terephthalate) industry*

Received October 15, 2023; Revised November 10, 2023; Accepted November 25, 2023

*** Dr. Emad Elwy Habib** is Associate professor at October for Modern Sciences and Arts University.
Email: dremadelwy@gmail.com
****Mr. Amr Gouda Hassanein** is a student at Arab Academy for Science, Technology and Maritime Transport, Egypt. Email: amrgouda22@hotmail.com

บทคัดย่อ

ลีนซิกซ์ซิกม่า (LSS) ได้รับการยอมรับอย่างแพร่หลายในวงการอุตสาหกรรมตลอดทศวรรษที่ผ่านมา งานวิจัยนี้มีจุดมุ่งหมายเพื่อเข้าใจผลกระทบของการประยุกต์ใช้ LSS ต่อการลดระดับขยะในอุตสาหกรรม วัตถุประสงค์ของการศึกษานี้เพื่อให้เข้าใจประสิทธิภาพของลีนซิกซ์ซิกม่า (LSS) งานวิจัยนี้ใช้ทั้งแนวทางเชิงพรรณนาและเชิงประจักษ์ โดยพิจารณาเฉพาะอุตสาหกรรม PET เท่านั้น แหล่งข้อมูลหลักได้มาจากการสำรวจ และข้อมูลรองได้มาจากบริษัท I.V.L Dhunseri Polyester ชุดข้อมูลประกอบด้วย 366 ข้อมูลการสังเกตเวลาของระดับขยะ วิธีการที่ใช้คือการวิเคราะห์ปัจจัยเชิงสำรวจเพื่อลดขนาด ตามด้วยการวิเคราะห์องค์ประกอบเชิงยืนยัน (CFA) แบบจำลองสมการโครงสร้าง (SEM) และการวิเคราะห์อนุกรมเวลาที่รวมกับตัวแบบ ARIMA ทำการวิเคราะห์เชิงพรรณนาผ่านแผนภูมิวงกลม และคำนวณค่าเฉลี่ยและค่าเบี่ยงเบนมาตรฐานตามมาตรวัดลิเคอร์ท จากการวิเคราะห์ข้อมูลเชิงลึกโดยใช้พาเรโต พบว่ามีปัญหาที่เกิดขึ้นในกระบวนการโซ่อุปทาน หนึ่งในปัญหาที่รายงานมากที่สุดคือค่าใช้จ่ายที่ไม่จำเป็นและของเสียจากขยะ ซึ่งสร้างแรงจูงให้กับบริษัท I.V.L Dhunseri Polyester ที่จะพิจารณาใช้ LSS การวิจัยนี้พบว่ามีการเพิ่มขึ้นอย่างมีนัยสำคัญทั้งประสิทธิภาพและประสิทธิผลทางกำไร ด้วยขนาดตัวอย่างที่ใหญ่จึงใช้การทดสอบทางสถิติ โดยรวมระดับขยะแตกต่างกันก่อนและหลังการประยุกต์ใช้ LSS พบว่าทุกคำอธิบายมีความเชื่อถือได้และถูกต้อง เมื่อนำการวิเคราะห์องค์ประกอบเชิงยืนยันมาใช้ พบว่ามีความสัมพันธ์ที่สำคัญระหว่างการประยุกต์ใช้ LSS ในห้ากระบวนการและการลดระดับขยะ โมเดล ARIMA (1,1,2) แสดงความเหมาะสมของข้อมูลอย่างดี การประยุกต์ใช้ LSS พบว่ามีผลกระทบเชิงลบต่อระดับขยะ

คำสำคัญ: ลีนซิกซ์ซิกม่า การจัดการคลังสินค้า การจัดการขยะ บริษัท I.V.L Dhunseri Polyester อุตสาหกรรม PET

INTRODUCTION

Waste management involves balancing goals of recycling and protecting consumers from hazardous chemicals in recycled materials; inadequate data collection; recycling quality issues; energy recovery from waste; and waste prevention. For example, companies involved in the various phases of the supply chain could assess product improvements to efficiently generate less waste or focus on incorporating greener, safe, and reliable materials into the operating process (Mahajan & Vakharia, 2016).

Gadde et al. (2010) found that each supply chain input would accumulate materials. This concept distinguishes a "direct supply chain," an “extended supply chain," and an "ultimate supply chain." The reverse supply chain would handle this. It also recirculated through the supply chain. Based on this paradigm, companies in the chain can choose a proactive approach to waste reduction or a reactive approach to reusing and recycling to manage waste across the supply chain (Mahajan & Vakharia, 2016; Patel & Patel, 2021).

Lean and six sigma applications in supply chain management have been studied, such as six sigma design to establish IT solutions for effective interdepartmental information exchange with supply chain operations (Gultom & Wibisono, 2019). Cross-functional information exchange improves supply chain performance (Linderman et al., 2002). Due to the warehouse's critical role in the supply chain, another study used lean techniques to maximize it. Lean and six sigma are being used more in supply chain management, but their effects on performance are still rarely studied. Lean manufacturing and supply chain efficiency are linked in recent research (Salah et al., 2010; Thomas et al., 2016).

Lean Six Sigma reduces waste and faults to improve performance. It combines Lean Manufacturing and Lean firm concepts. Six Sigma approaches and technologies reduce waste of material resources, time, talent, and effort while improving manufacturing processes (Singh & Rathi, 2019). (LSS) is vital for firms to simplify production and provide high-quality goods (Antony & Hoerl, 2017; Patel & Patel, 2021).

Waste reduction or source reduction reduces rubbish and conserves resources by using less material and energy. Trash reduction involves recycling and preventing waste before recycling. Reusing plastic and glass containers, choosing stronger products, and using dishrags instead of paper towels save waste. Donating clothes, furniture, and office supplies reduces waste (Vollmer et al., 2020).

This study would address the PET industry's warehouse waste research need. It will also be the first to quantitatively analyze this problem. Other study has highlighted how lean six sigma should be used, but not how it will impact supply chain management and waste reduction. It would solve supply chain issues and waste expenses.

LITERATURE REVIEW

Lean Six Sigma (LSS)

Lean Six Sigma (LSS) is the result of Lean development and Six Sigma integration, which has gained attention in recent years due to the need to deliver business value to customers in a rapidly changing environment and take end-user needs into account. For building an exploit quality enhancement tool, both techniques should be used (Maliev et al., 2012; Jick & Sturtevant, 2017; Singh & Rathi, 2019). In the early phases of Six Sigma, many organizations struggled to increase productivity and product cost, but they gained a quality brand image (Besseris, 2014).

Lean and six sigma roadmaps should be regarded new possibilities and derivatives of total quality management (TQM) roadmaps after comparing several quality improvement activities. Innovative statistical techniques and technologies have replaced the most current vision of quality mainstream development in fundamental curricula based on earlier stages. This caused intermittent change by noticing considerable process improvements and organizational productivity increases, which added company value to customers (Yadav and Desai, 2016).
Since lean six sigma has intensified over the past decade, manufacturers embraced it. This method mixes lean and six sigma, which have different purposes. (Yadav and Desai 2016; Gultom and Wibisono 2019). Lean eliminates waste to improve value stream operations. Lean and six sigma applications are thought to affect performance because manufacturing firms' supply chains are represented in the value stream (Gultom and Wibisono 2019). Lean aims for zero faults and little process variation (Anđelković et al., 2016), while six sigma seeks to improve process capabilities in the value stream.

Khalil et al. (2021) found that Six Sigma tools directly affect team performance and mediate the relationship between organizational objectives and six sigma. Thus, correct visualization is needed to deploy any corporate technology or process. Thus, consistent research outcomes make analytical literature reviews essential for analyzing, amassing, and stacking research area information. Research reproducibility and argument and conclusion quality demand more systematic techniques (Linderman et al., 2006).

Lean six sigma's benefits include variants that give a broad range of values for particular activities, processes, items, and services. Lean sigma requires fast, high-quality work. It may also increase a company's profitability and operational efficiency to meet and exceed customer expectations (Makwana & Patange, 2021). Kanban, just-in-time, and kaizen underpin lean. The reduction of seven wastes includes excessive and overproduction, defects and rejections, overstock, improper processing, uncontrolled transportation, waiting and idleness, and unnecessary/redundant motion (Adnan et al., 2013; García-Alcaraz, 2019).

According to Laureani and Antony (2012), LSS is a corporate development approach that maximizes shareholder value by improving costs, speed, quality, and customer happiness. Statistically, Six Sigma identifies process opportunities that could lead to defects to prevent quality problems, while Lean eliminates waste by excluding non-value-adding activities (Anthony et al., 2005). Lean eliminates waste by eliminating non-value-added operations (Antony et al., 2005). LSS is a composite process that helps firms pinpoint client needs, eliminate non-value-added processes, reduce production process unpredictability, and improve organizational performance (Schroeder et al., 2008).

DMAIC phases solve the "failure to build the nozzle with precise hole diameter" problem. In the define phase of the DMAIC, a team used Pareto analysis sheets to analyze nozzle manufacturing data from the previous year (Srinivasan et al., 2016). A coordinate measuring apparatus assessed the drilling hole variation during measurement. During a brainstorming session in the analysis phase of the DMAIC approach, a cause-and-effect diagram revealed key factors affecting hollow hole drilling (Srinivasan et al., 2016). LSS uses data-driven quality approach to improve operations (Daniyan et al., 2018).

Warehouse Performance in Supply Chain Management

Supply chain management emerged from the realization that turning raw materials into finished goods and delivering them to clients is becoming harder. Thus, improving supply chain echelons does not help the whole chain (Zekhnini et al., 2020). Thus, from raw materials to customer delivery, the supply chain included production. Only a flexible supply chain can maintain a competitive edge in a manufacturing environment where enterprises compete with supplier networks (Alfalla-Luque et al., 2018). Customer-driven product needs, shorter product lifecycles, and swift replacement make supply chain management more important than internal issues. Supply chain management integrates suppliers, manufacturers, warehouses, and stores to produce and distribute goods and services to customers in the right quantities, locations, and times while reducing costs and meeting service level requirements (Halim et al., 2011; Ramezankhani, 2018).

Halim & Habib (2020) say demand, shipment volume, and product quality might disrupt the supply chain. Fill, lead, and on-time delivery vary here. These theories linked lean supply chain performance assumptions (Gultom & Wibisono, 2019). Supply chain management differs from commercial supply networks (Gultom and Wibisono 2019). Halim et al. (2011) noted that any organization may be in several supply chains due to unlimited supply network topologies. Multiple supply chains explain its network-like structure. Lean and six sigma may increase performance since the value stream depicts industrial firms' supplier networks' continual operations (Valamede & Akkari, 2020). Chugani et al. (2017) found that lean six sigma affects warehouse metrics including time, inventory process, and defects.

Gultom & Wibisono (2019) define LSS as lean and six sigma, each with its own goals. Lean optimizes value streams by eliminating waste. To increase practicality, Six Sigma seeks zero defects and minimal process volatility. Since internal stream operations represent the value stream, lean and six sigma deployments could strengthen manufacturing businesses' supply networks (Daniyan et al., 2018).

According to Byrne et al. (2021), lean reduces the seven wastes of transportation, inventory, movement, waiting lines, overproduction, overprocessing, and defects to produce value and improve process flow. Lean indicators may predict quality and employee engagement, whereas six sigma indicators are variations. Supplier selection, delivery, logistics performance, manufacturing process, and storage affect supply chain performance to the extreme (Gultom & Wibisono, 2019).

Mabotja et al. (2018) examined warehouse management and supply networks. Thus, warehouse performance needed monitoring. It measured quality, time, inventory, and faults. The three researchers agreed that faults and waste affect warehouse performance.

Waste level Reduction: is anything other than the least amount of actions and supplies required to do the project right immediately, the first time, and to the customer's satisfaction (Bicheno and Holweg, 2008). As a multidimensional concept, warehouse waste elimination practices include receiving, warehousing, picking, and dispatching activities, according to Tahboub and Salhia (2019). Waste reduction starts with less stuff (Hill, 2018). Tahboub & Salhieh (2019) examined how trash reduction affects warehouse efficiency.

Kholil et al. (2021) examined the role and direct effect of lean six sigma integration in reducing waste in production with DMAIC and Value stream mapping VSM approach throughout the production lines of manufacturing companies. They argued that quality must be monitored by analyzing waste causes and levels. Value Stream Mapping visualized the aggregate production process and represented material flow as information flow for lean manufacturing (Goriwondo et al., 2011). DMAIC approach targeted for continuous improvement. Through assessing present processes and value stream mapping VSN, all types of waste along the value chain were identified and eliminated (Kholil et al., 2021).

Bag Quality: Bags must be in excellent condition to reduce waste and maximize material utilization (Hill, 2018). Gupta & Kumar (2014) used root causes approach using fish bone diagram to realize the various types of losses due to bag damage, such as bag cost, cost of extra labor, and revenue due to product devaluation. Following DMAIC approach to Six Sigma and pareto analysis chart helped focus on the most prominent root causes. Thus, logistics, quality control, and warehousing specialists might brainstorm ideas by examining flow process maps.

Bagging operation: Wastes may be damaged during packaging. The PET business calls it bagging (Hill, 2018). Value steam mapping (VSM) is used in design and trash disposal to reduce waste and improve flow and understanding of the value stream (Rother & Shook, 2003; Dadashnejad, 2018). Byrne et al. (2021) found that lean methods as a strategic approach can eliminate waste and minimize operational losses, such as equipment setup, changes, and failures, scrap and rework, inactive idle and downtime, running speed, start-up losses, and continuous improvement.

Fall from sacks: Hill (2018) argued that sacks are bags that full of any substances and there is a chance that a substance can escape of get our or fall which bring costs for the factories when they produce it. Since any material that can fall start being contaminated.

Store Handling: Kusrini et al. (2018) identified that warehousing activity consists of receiving, classification and coding, inspection, dispatching, put away, storage areas utilization, picking and shipping. Put away is the activity of placing a product or material that has been purchased in the warehouse, includes material handling activities to check the location of the product material and product placement (Chakraborty et al., 2007; Öztürkoğlu, 2018; Kusrini et al., 2018). otherwise known as finished goods handling, it is one of the main reason of wastes in PET industry. Hill (2018) resulted in that a high percentage of wastes can occur due to the handling stage.

Stuffing and packing: Loading and filling containers with commodities to maximize container capacity and preserve items during storage and transport (Baskar & Pragadeeswaran, 2017; Cahyono & Pujawan, 2019; Durai & Kannan, 2021). Stuffing is packing objects in PET bags or sacks. Stuffing may cause several mistakes. Company losses might be substantial (Hill, 2018).

RESEARCH PROBLEM

As many unforeseen consequences can arise from managing waste level reduction as there is currently plagued by several problems, capacity challenges with logistics providers, rising freight costs, bag quality, bagging operation, huge staffing of waste, falling stacks. Lean Six Sigma was introduced as alternative solution to many issues concerning the warehouses process. It identifies and eliminates root causes of errors and lower variance in reduction processes.

Research Hypotheses

H1: There are significant differences between the waste level before and after Lean Six Sigma application

H2: Lean six sigma has a significant positive effect on waste level reduction.

Research Objectives

a. Define the problems which occurs in the supply chain processes and benefits of the usage of Lean Six Sigma.
b. Compare the difference in the waste level between before and after application of Lean Six Sigma.
c. Investigate the effect of lean six sigma on the waste level reduction.

Research Questions

After understanding the variables that should be handled, the research question should be defined. The main research question is whether or not the lean six sigma improve supply chain performance. This is studied through tackling a number of sub questions

1. What is the Lean Six Sigma? How can it be applied?
2. What is the waste level as an indicator of supply chain performance?
3. What are the common problems that face supply chain performance and can be solved by lean six sigma?
4. What are the advantages of applying Lean six sigma?
5. Is there is a difference between the waste level before and after applying lean six sigma?
6. Is there an improvement in the waste level upon applying lean six sigma?

7. What are the recommendations to PET industry firm posed upon the findings of this study?

Case studies using Lean Six Sigma

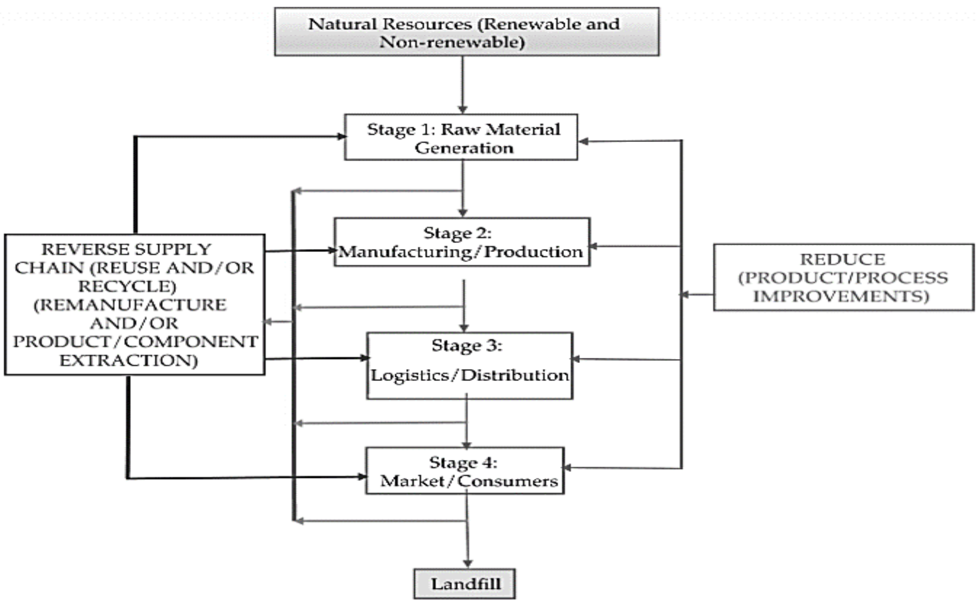
Lean six sigma has been shown to improve supply chain performance and waste levels, notably in FMCGs (Shekarian et al., 2020). Fibers, films, and molding materials are made from PET. PET supplies 40% of synthetic fibers worldwide. PET production is 5 million tons, and consumption is predicted to reach 10 million tons by 1990 (Lufkin, 1981).

Numerous fundamental studies on the synthesis, structure, properties, and uses of this essential polymer have been published (Ravindranath and Mashelkar, 1985). This polymer's chemical and engineering properties have not been properly explored.

Polyethylene terephthalate (PET) is a popular engineering polyester thermoplastic with high thermal, mechanical, and chemical resistance. Technical applications, textile fabrics, and food and beverage containers use it. Egyptian firm Dhunseri Polyester is a key participant. It is a major Middle East and African PET manufacturer. Waste management issues plague the company.

In the PET industry, lean six sigma research on supply chain and waste management is scarce. Hassan (2013) examined how lean six sigma reduces waste. However, it remains one of the studies that best understood the LSS influence on supply chain management and waste reduction. The literature shows that lean six sigma is the development of lean manufacturing and six sigma. Figure (1) shows how the 3Rs influence enterprises at each stage of the conventionalized and formalized supply chain. From a reduction perspective, companies in all phases of the supply chain would need to assess product improvements to generate waste reduction and elimination (for example, through initiatives like design for the environment) or focus on incorporating more environmentally safe materials in their operations (Mahajan & Vakharia, 2016).

Figure 1: Description of Relationship between Supply Chain and Waste Reduction



Source: Mahajan & Vakharia (2016)

METHODOLOGY

The purpose of the study that will be used is to understand the effectiveness of Lean Six Sigma. The research will take a descriptive approach. The approach chosen to tackle this problem would be the quantitative analysis approach. A survey was conducted on warehouse, logistics and quality departments in the PET industry. CFA and SEM were applied to test hypotheses.

The secondary data was obtained from Indorama Dhunseri company. The T paired test was to check the difference between the waste level before and after applying Lean Six Sigma. a time series analysis model specifically the ARIMA model is used. Pareto analysis combined with the failure effect model analysis. These two analysis types would give a clearer image on the situation of the firm and how the LSS was applied in order to obtain the required results. It will also deal with the hidden processes and meaning behind the results obtained and give stronger evidence that LSS either effective or not. To assess the suitability of the suggested model, an iterative three-stage method, consisting of model identification, parameter estimate, and diagnostic check, is needed. In essence, ARIMA modelling is a data-driven exploratory technique with the flexibility to build a suitable model that is derived from the data's structure.

The dataset was collected through cluster random sampling. The cluster contain heterogenous elements. All the elements should be reviewed (Soma & Meeden, 2021). In the case of the thesis, the I.V.L. Dhunseri was randomly selected from sampling frame of all companies in Middle East. The dataset consisted of 100 interviewees working in warehouse, 40 in the logistics department and only 12 in the supply chain department. The portion of officers were more than the proportion of managers. The managers in the interviewed sample were only 3 while around 8 associates were present and the rest were officers and employees interviewed.

The secondary data was obtained from I.V.L. Dhunseri as well. It consisted of 366 observations of time series data points for waste levels. It mentioned the waste sources and the total wastes for each day. The daily basis data provided an excellent stationary dataset that could be further used in ARIMA model building. Also, the experts in I.V.L. Dhunseri provided the required information to build failure effect mode analysis.

Proposed framework of the study

Figure 2: Chart Presenting the Variables in the Study

Source: Based on Daniyan *et al*. (2022); Hill (2018)

RESULTS AND DISCUSSION

The paired T test was applied to differentiate and compare waste level.

Table l: Paired T test for Defects before and after Application of LSS in Different Reasons

Reason	Paired T test
Bag quality	-0.816
Bagging	42.428**
Stuffing	-77.000**
Falling from sack	-42.428**
Due to FGS	-42.435**
****<0.01,*<0.05, “ ”>0.05**	

Source: Based on sampled surveys

When Paired T test was computed to compare between the opinion about existence of problems before and after application of LSS. The opinions about defects due to bag quality was believed to be equal before and after the LSS. The bagging quality was believed to get worsen after applying LSS. Concerning the defects due to stuffing, falling from sack and FGS, it was found to be improving in the point of view of the experts after application of LSS. Overall, the opinions tend to believe there is a change between before and after application of LSS.

Table 2: Paired T test of before and after Application of Lean Six Sigma on I.V.L. Dhunseri Warehouse Data

	Mean	Paired T value
Difference between before and after application of lean six sigma	153.428	2.779*
**<0.01, *<0.05, “ ”>0.05		

Source: Based on I.V.L. Dhunseri warehouse data year 2020

There is a significant different in waste level between before and after application of LSS for different types of wastes. The average difference between the two phases is 153.428 which indicate a decrease in waste level after the application of LSS. The paired T test was computed on the dataset provided by I.V.L. Dhunseri to understand the effect of LSS on waste level in general taking into consideration all types of waste levels. In general, there is an effect of LSS on waste level.

In conclusion, the T paired test shall be used due to the relatively large sample size. There is a significant different in waste level between before and after application of LSS for different types of wastes. The bagging quality was believed to get worsen after applying LSS. Concerning the defects due to stuffing, falling from sack and FGS, it was found to be improving in the point of view of the experts after application of LSS. In general, the waste level was different from before and after application of LSS. Thus, approving the second hypothesis.

H2*:* There is an effect of applying Lean Six Sigma on the performance of supply chain

The last hypothesis needed to understand the effect of the application of lean six sigma with its five procedures DMAIC on the waste reduction. It was done through confirmatory factor analysis and structural equation modelling. Also, the secondary data obtained from I.V.L.

Dhunseri was analyzed using Time series analysis. In addition to that a Pareto analysis and FEMA were conducted to understand the effect better.

Confirmatory Factor analysis

Table 3: Reliability and Validity Measures for Variables of Study after Application of CFA

	Cronbach alpha	Composite reliability	Average Variance Extracted
DAC	0.810	0.888	0.725
MI	0.674	0.853	0.745
Waste reduction	0.802	0.866	0.684

Source: Based on sampled surveys

There were some issues due to reliability so the independent variable of applying LSS had to be divided into two variables one presenting the definition, analyzing and control. The other is the measuring and improvement. Taking into consideration that other statements had to be removed due to lack of reliability.

CFA is applied to observe reliability and validity of factors obtained from the application of EFA. The reliability was measured by Cronbach alpha. All of the variables had a Cronbach alpha higher than 0.6. Therefore, all the statements are reliable to represent the factors in the study. To approach the validity of the statements in expressing the factors, both the composite reliability and the average variance extracted were computed. The AVE of each factor were above 0.5 and the CR was above 0.7. This shows how the statements was valid to be used for the factors.

Structural equation modelling

Table 4: Reliability and Validity Measures for Variables of Study after Application of SEM

	Cronbach alpha	Composite reliability	Average Variance Extracted
DAC	0.810	0.888	0.725
MI	0.674	0.853	0.745
Waste reduction	0.802	0.866	0.684

Source: Based on sampled surveys

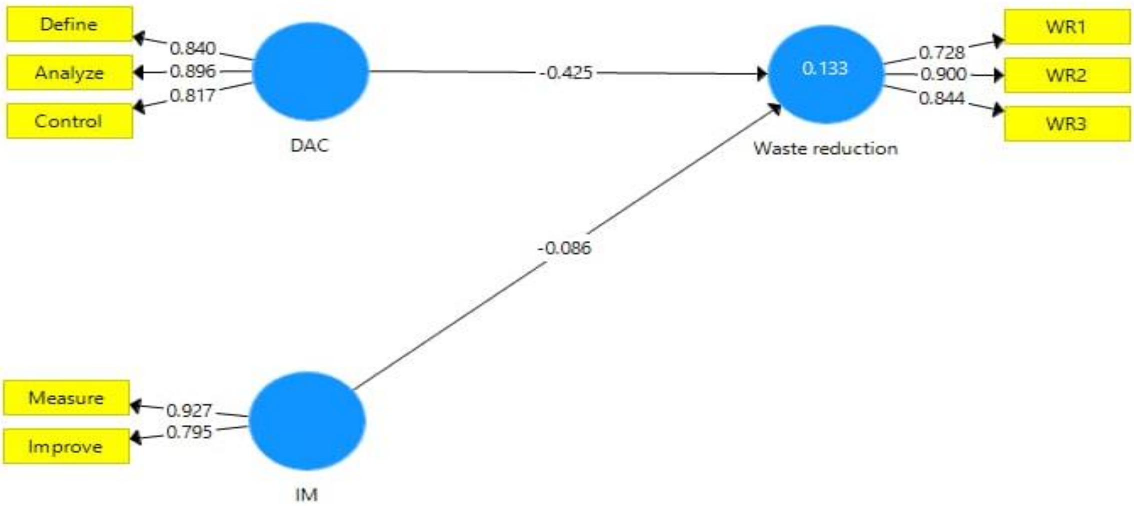
CFA is applied to observe reliability and validity of factors obtained from the application of EFA. The reliability was measured by Cronbach alpha. All of the variables had a Cronbach alpha higher than 0.6. Therefore, all the statements are reliable to represent the factors in the study. To approach the validity of the statements in expressing the factors, both the composite reliability and the extracted average variance were computed. The AVE of each factor were above 0.5 and the CR was above 0.7.

Figure 3 shows how the relationships are built in the structural equation model. All the loading are above 0.7 which gives an indication that no statements shall be removed from the study.

After applying the SEM, the phenomenon was more understood. There was a significant relationship between the application of LSS 5 processes and level of waste reduction by 95%

level of confidence. So, the hypotheses that application of LSS have a positive effect on solving the issues concerning wastes and additional unnecessary cost is accepted (Table 5).

Figure 3: Structural Equation Model for Application of LSS on Waste Reduction Level



Source: Based on sample surveys

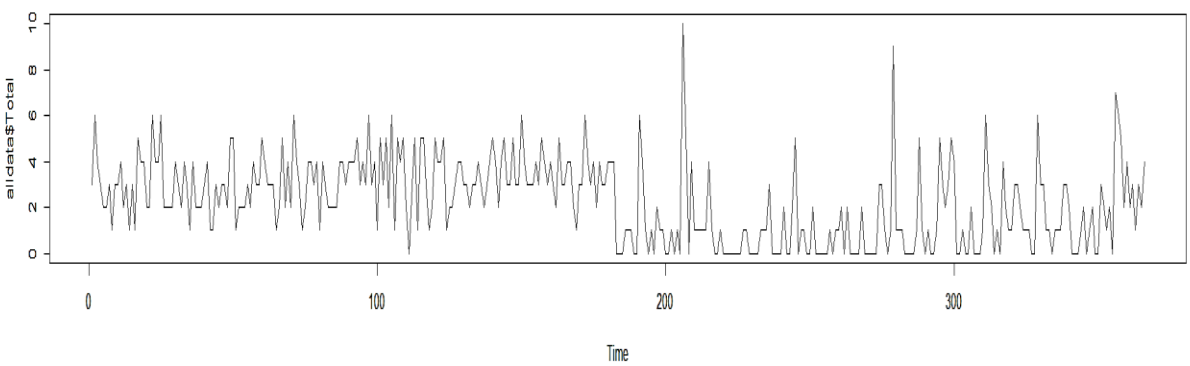
Table 5: Estimates for SEM and Standard Deviation

	Original samples	Standard deviation
DAC->Waste reduction	0.479	0.165*
MI->Waste reduction	0.571	0.014*

Source: Based on sample surveys

Time Series Analysis

Figure 4: Linear Trend based on I.V.L. Dhunseri



Source: Based on I.V.L. Dhunseri warehouse data year 2020

In figure 4, the linear trend showed after the 183rd observation a sudden decline in the waste level. The occurrence is justified by the LSS application on waste level.

Table 6: Dickey-fuller Test on Dataset to Check on White Noise

	Dickey-fuller test statistic	Lag order
Data of waste level	-4.0262*	7

**<0.01,*<0.05, " ">0.05

Source: Based on I.V.L. Dhunseri warehouse data year 2020

Since the Dickey fuller test had a null hypothesis of non-stationarity and an alternative hypothesis of stationarity, the test statistics was found to be significant. Thus, the data provided by I.V.L. Dhunseri in year 2020 was found to be stationary. This would satisfy the stationarity assumption that is required to build an ARIMA model.

Dummy ARIMA Model building

Table 7: Dummy ARIMA Model for Waste Reduction Level for Data provided by I.V.L. Dhunseri

	Estimate	Standard error
AR (1)	0.1721	0.1711
MA (1)	-0.5856	0.1689
MA (2)	-0.2009	0.1136
Lean Six Sigma Application	-190.5987	91.8123

Source: Based on I.V.L. Dhunseri warehouse data year 2020

A dummy ARIMA (1,1,2) was fitted for data. The lean six sigma application entered the model as a dummy variable as explained in the data management section. It was found to have a significant negative effect on the waste level. It decreased the wastes by nearly 190.6 units since it was applied in I.V.L. Dhunseri. Since AR (1)>0, this shows an increase in waste level along the time. The moving averages MA (1) and MA (2) represent the moving average of the last 2 error terms with weights equal -0.586 and -0.2. Therefore, the model would be built by

$$\widehat{Y_t} = 0.1721\, Y_{t-1} - 0.5861\epsilon_{t-1} - 0.2009\epsilon_{t-2} - 190.5987D, \qquad D = 0, 1$$

Table 8: Performance Measures for Data provided by I.V.L. Dhunseri

	AIC	BIC	MAPE
Value	4539.29	4558.79	7.469621

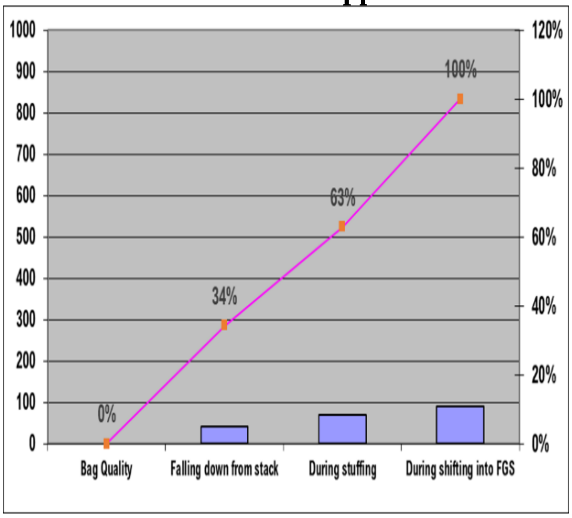
Source: Based on I.V.L. Dhunseri warehouse data year 2020

The performance measures for the model were computed. The Akaike information criterion was found to be 4539.29. The Bayesian information criterion was found to be 4558.79. Those two measures showed high performance of the model. The Mean Absolute Percentage Error was found to be low and equal to 7.469621 showing how relatively good model.

After showing the evidence, it can be concluded as a good fit model. This indicate that the results provided by model is approved. This proves that, applying lean six sigma led to lower waste level. Thus, it has an effect on supply chain performance. The second hypothesis is then approved.

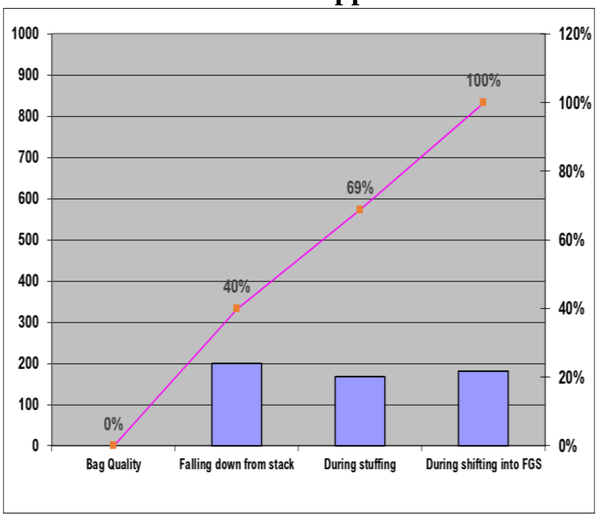
In summary, applying CFA to the survey's responses, all the statements were found to be reliable and valid. After modelling, there was found a significant relationship between the application of LSS 5 processes and level of waste reduction. Concerning the data from I.V.L. Dhunseri, the data provided by I.V.L. Dhunseri in year 2020 was found to be stationary. The ARIMA models built for the two periods individually compared showing that each has its own behaviour. A dummy ARIMA (1,1,2) was a good fit for data. The application of lean six sigma was found to have a significant negative effect on the waste level. It decreased the wastes by nearly 190.6 units since it was applied in I.V.L. Dhunseri. Thus, approving the second hypothesis
To observe the effect of LSS on the warehouse management, the pareto analysis and FEMA were applied.

Figure 5: Pareto Analysis for the Waste due to Different Reasons before Application of LSS



Source: Based on I.V.L. Dhunseri warehouse data year 2020

Figure 6: Pareto Analysis for the Waste due to Different Reasons after Application of LSS



Source: Based on I.V.L. Dhunseri warehouse data year 2020

It appears to be eliminating the bagging operation wastes from the pareto analysis. In the pareto analysis, it was recommended to focus on rest of wastes sources. Those falling from stacks were the highest reaching a level of 200. The bag quality was nearly 0%. It reached 100% cumulatively by focusing on those wastes that occur during shifting into FGS.

After applying LSS, it appears to be eliminating the bagging operation wastes from the pareto analysis. In the pareto analysis, it was recommended to focus on rest of wastes sources. Those falling from stacks became the lowest level of wastes. This shows the success of LSS in reducing wastes. The bag quality was nearly 0%. It reached 100% cumulatively by focusing on those wastes that occur during shifting into FGS. All the sources of wastes experienced lower level of wastes after applying LSS.

Table 9: Performance of Supply Chain based on Pareto Analysis applied on I.V.L. Dhunseri

<table>
<tr><td></td><td colspan="2">Application of LSS</td><td rowspan="3">Total amount saved</td><td rowspan="2">Financial benefit</td></tr>
<tr><td rowspan="2">% Of repacking</td><td>Before</td><td>After</td></tr>
<tr><td>0.305%</td><td>0.114%</td><td>5759$/year</td></tr>
</table>

Source: Based on I.V.L. Dhunseri warehouse data year 2020

Table 10: Failure Effect Mode Analysis in I.V.L. Dhunseri Year 2020

Failure Effect Mode Analysis											
Process Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Prob	Current Design Controls	Det	RPN 1st half 2020	RPN 2nd half 2020	Diff
			1 to 10		1 to 10		10 to 1	= S x P x D		
Finished product Bagging	Bag damaged	Neck damaged	6	Wrong clamping	2	Bagging machine maintenance	7	84	108	24
		Poor Bag Quality	5	Initial inspection failed	1	Taken from approved suppliers, Quality inspection per lot	8	40	90	50
		Wrong dimension	4	Varying dimension for different types of pkg.	1	Dimension standardized	8	32	80	48
Finished bag shifting & storing into FGS	Bag damaged	Bag handle damage	7	Bad quality, improper lifting	4	Trained driver	7	196	196	0
		Bag perforated by fork	5	Uncontrolled Forklift movement, inadequate space	4	Speed limit defined	8	160	160	0
		Reaching max capacity	8	tight maneavour space and cosed corridors	3	TBD	5	120	NiL	
Bag preloading from stacked bins	Bag damaged	Fall down from stacks	8	Inclined or tilled stacking, Multilayer loading	3	Trained driver assisted by operator	7	168	168	0
		Improper stacking of bags over pallet	6	Bottom layer not positioned centrally over the pallet	3	Trained driver assisted by operator	6	108	108	0
Stuffing of bags	Bag damaged	Damaged while loading into container	5	Loading performed without taking care of the container height	2	Trained driver assisted by operator	7	70	75	5
		Damaged while loading on the trucks	5	Bags fall down from open truck or truck floor not smooth enough	1	Trained driver assisted by operator	7	35	75	40

Source: Based on I.V.L. Dhunseri warehouse data year 2020

The percentage of repacking which is an indicator of waste level was 0.305% before applying LSS. It decreased significantly to 0.114% after applying the LSS. Another important indicator is the financial benefit that result from applying LSS. It happened to be 5759$ a year. This shows how LSS plays as a perfect alternative for the problems concerning the supply chain performance and specifically waste reduction.

It is noticed that the bagging operations have the highest failure rates. This goes consistently with the results from pareto analysis. Those occurring from stacking bins and shifting into FGS had nearly zero failures. However, stuffing caused two kind of wastes which is damages due to loading containers and damaging due to loading trucks. Loading into trucks caused higher rates of failure and it would be solved by training drivers and assisting them by operators.

CONCLUSION AND LIMITATION

Conclusion

Finally, company waste may lead to loss and inefficiency. The answer was lean six sigma. I.V.L. Dhunseri was a sample of Middle Eastern PET industrial businesses for this research. Data was primary and secondary. Lean six sigma evolved from lean manufacturing and six sigma, according to the literature. This evolution outperformed standard approaches. DMAIC applied LSS. Waste reduction measured supply chain management performance.

Supply chain management KPIs were easily seen in literature. Waste reduction as a performance measure was seldom studied. Most studies weren't quantitative. Instead, long-form surveys were considered. This thesis used primary and secondary data for statistical analysis. The T paired test demonstrated substantial waste level differences before and after LSS treatment for distinct waste kinds. After LSS, bagging quality deteriorated. LSS improved filling, falling from sack, and FGS flaws, according to experts. LSS changed waste levels overall. Later, a dummy ARIMA model described data and showed how lean six sigma reduced waste. Data fit dummy ARIMA (1,1,2). The model's AR terms were positive, indicating waste growth. Lean six sigma application dummy variable has a negative significant coefficient. It cuts waste by 191 units. A CFA showed the survey statements were trustworthy and valid to convey the variables. SEM showed that lean six sigma significantly reduces waste. The thesis conclusions accepted the two assumptions.

Limitation

A number of limitations faced the research as the application of this research only took into consideration the PET industry. No other industries were represented in this research. The study was applied only on the waste reduction level of the inventory of finished goods. No other measures of performance were taken into consideration. The cluster chosen contained all the I.V.L. Dhunseri employees and this considered all the companies in the field of PET industry to be similar in the financial and supply chain structure.

Acknowledgement

This research was supported by I.V.L. Dhuneri which provided the needed data to complete the analysis. The authors would like to thank them for their cooperation.

REFERENCES

Adnan, A. N. B., Jaffar, A. B., Yusoff, N. B., & Halim, N. H. B. A. (2013). Implementation of just in time production through Kanban system. *Industrial Engineering Letters*, *3*(6).

Alfalla-Luque, R., Machuca, J. A., & Marin-Garcia, J. A. (2018). Triple-A and competitive advantage in supply chains: Empirical research in developed countries. *International Journal of Production Economics, 203*, 48-61.

Anđelković, A., Radosavljević, M., & Stošić, D. (2016). Effects of lean tools in achieving lean warehousing. *Economic Themes, 54*(4), 517-534.

Antony, J., Kumar, M., & Madu, C. N. (2005). Six sigma in small- and medium-sized UK manufacturing enterprises. *International Journal of Quality & Reliability Management, 22*(8), 860–874.

Antony, J., Snee, R., & Hoerl, R. (2017). Lean Six Sigma: yesterday, today and tomorrow. *International Journal of Quality & Reliability Management, 34*(7), 1073-1093.

Baskar, M. B., & Pragadeeswaran, S. (2017). A Study of the Priority Constraints of Container Stuffing Process of International Logistic System. *International Research Journal of Management Science & Technology, 8* (8), 2348 – 9367. ISSN 2250 – 1959.

Besseris, G. (2014). Multi-factorial lean Six sigma product optimization for quality, Leanness and safety. *International Journal of Lean Six Sigma, 5*(3), 253–278.

Bicheno, J., & Holweg, M. (2008). The Lean toolbox: The essential guide to Lean transformation. Picsie Books.

Byrne, B., McDermott, O., & Noonan, J. (2021). Applying lean six sigma methodology to a pharmaceutical manufacturing facility: A case study. *Processes, 9*(3), 550.

Cahyono, H., & Pujawan, I. N. (2019). Analysis of Empty Containers Supplies in the Shipping Network: Case Study at National Shipping Company. *IPTEK Journal of Proceedings Series,* (5), 441-451.

Cahyono, H., & Pujawan, I. N. (2019). Analysis of Empty Containers Supplies in the Shipping Network: Case Study at National Shipping Company. *IPTEK Journal of Proceedings Series,* (5), 441-451.

Chakraborty, P. S., Majumder, G., & Sarkar, B. (2007). Performance evaluation of material handling system for a warehouse.

Dadashnejad, A. A., & Valmohammadi, C. (2018). Investigating the effect of value stream mapping on operational losses: a case study. *Journal of Engineering, Design and* Technology, *16*(3), 478-500.

Daniyan, I., Adeodu, A., Mpofu, K., Maladzhi, R., & Kana-Kana Katumba, M. G. (2022). Application of lean six sigma methodology using DMAIC approach for the improvement of bogie assembly process in the railcar industry. *Heliyon*, *8*(3).

Durai Murugan, S., & Kannan, V. (2021). A Study on cargo transportation damage reduction at company, TUTICORIN. *International Research Journal of Modernization in Engineering Technology and Science,* (3), 665-673.

Durai Murugan, S., & Kannan, V. (2021). A study on cargo transportation damage reduction at shipping company, Tuticorin. *International Research Journal of Modernization in Engineering Technology and Science,* (3), 665-673.

Habib, E. (2015). Logistics Chain Processes KPIs in The Egyptian Food Processing Industry. *Scientific Journal of Economics and Trade*, *45*(3), 33-70.

Gadde, L. E., Håkansson, H., & Persson, G. (2010). *Supply Network Strategies*. John Wiley & Sons.

García-Alcaraz, J. L., Realyvasquez-Vargas, A., García-Alcaraz, P., Perez de la Parte, M., Blanco Fernandez, J., & Jimenez Macias, E. (2019). Effects of human factors and lean techniques on just in time benefits. *Sustainability, 11*(7), 1864.

Goriwondo, W. M., Mhlanga, S., & Marecha, A. (2011). Use of the Value Stream Mapping tool for Waste Reduction in Manufacturing. Case Study for Bread Manufacturing in Zimbabwe.

Gultom, G. D. P., & Wibisono, E. (2019, May). A framework for the Impact of lean six sigma on supply chain performance in manufacturing companies. In IOP Conference Series: Materials Science and Engineering (Vol. 528, No. 1, p. 012089). IOP Publishing.

Gupta, K., & Kumar, G. (2014, October). Six Sigma application in warehouse for damaged bags: a case study. In Proceedings of 3rd International Conference on Reliability, Infocom Technologies and Optimization (pp. 1-6). IEEE.

Halim, Y. T., Eldeeb, M. S., Habib, E. E., & Bassim, M. A. (2011). Supply Chain Performance Evaluation Through Eva in Hospitality. Available at SSRN 1874931.

Hassan, M. K. (2013). Applying lean six sigma for waste reduction in a manufacturing environment. *American Journal of Industrial Engineering, 1*(2), 28-35.

Hill, K. (2018). Lean manufacturing: 'The Seven Deadly Wastes': Find greater efficiency at every step of the process. *Plant Engineering, 72*(2), 10-12.

Jick, T. D., & Sturtevant, K. D. (2017). Taking stock of 30 years of change management: is it time for a reboot? In Research in organizational change and development (Vol. 25, pp. 33-79). Emerald Publishing Limited.

Kholil, M., Haekal, J., Suparno, A., Savira, D., & Widodo, T. (2021). Lean Six sigma Integration to Reduce Waste in Tablet coating Production with DMAIC and VSM Approach in Production Lines of Manufacturing Companies. *International Journal of Scientific Advances*, *2*(5), 719-726.

Kusrini, E., Novendri, F., & Helia, V. N. (2018). Determining key performance indicators for warehouse performance measurement–a case study in construction materials warehouse. In MATEC Web of Conferences (Vol. 154, p. 01058). EDP Sciences.

Laureani, A., & Antony, J. (2012). Critical success factors for the effective implementation of Lean Sigma: Results from an empirical study and agenda for future research. *International Journal of Lean Six Sigma*, *3*(4), 274-283.

Linderman, K., Schroeder, R. G., & Choo, A. S. (2005). Six sigma: The role of goals in improvement teams. *Journal of Operations Management, 24*(6), 779–790.

Linderman, K., Schroeder, R. G., Zaheer, S., & Choo, A. S. (2002). Six sigma: A goal-theoretic perspective. *Journal of Operations Management, 21*(2), 193–203.

Mahajan, J., & Vakharia, A. J. (2016). Waste management: A reverse supply chain perspective. *Vikalpa: The Journal for Decision Makers, 41*(3), 197–208.

Maleyeff, J., Arnheiter, E. A., & Venkateswaran, V. (2012). The continuing evolution of Lean Six Sigma. *The TQM Journal, 24*(6), 542–555.

Öztürkoğlu, Ö. (2018). Lean and Sustainable Warehousing. In Handbook of Research on Supply Chain Management for Sustainable Development (pp. 218-241). IGI Global.

Patel, A. S., & Patel, K. M. (2021). Critical review of literature on Lean Six Sigma methodology. *International Journal of Lean Six Sigma, 12*(3):627-674.

Permana, A., Purba, H. H., & Rizkiyah, N. D. (2021). A systematic literature review of Total Quality Management (TQM) implementation in the organization. *International Journal of Production Management and Engineering, 9*(1), 25-36.

Polyethylene Terephthalate Global Market Report 2022.

Polyethylene Terephthalate Global Market Report 2023.

Ramezankhani, M. J., Torabi, S. A., & Vahidi, F. (2018). Supply chain performance measurement and evaluation: A mixed sustainability and resilience approach. *Computers & Industrial Engineering*, *126*, 531-548.

Rother, M., & Shook, J. (2003). Learning to see: value stream mapping to add value and eliminate muda. Lean enterprise institute.

Roy, S., Kumar, K., & Satpathy, B. (2021). Strategic planning of optimising productivity: a'5S under lean quality'approach. *International Journal of Productivity and Quality Management, 32*(1), 53-71.

Salah, S., Rahim, A., & Carretero, J. A. (2010). The integration of Six Sigma and lean management. *International Journal of Lean Six Sigma, 1*(3), 249-274.

Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. (2007). Six sigma: Definition and underlying theory. *Journal of Operations Management, 26*(4), 536–554.

Shekarian, M., Nooraie, S. V. R., & Parast, M. M. (2020). An examination of the impact of flexibility and agility on mitigating supply chain disruptions. *International Journal of Production Economics, 220*, 107438.

Singh, M., & Rathi, R. (2019). A structured review of Lean Six Sigma in various industrial sectors. *International Journal of Lean Six Sigma, 10*(2), 622-664.

Soma, M., & Meeden, G. (2021). A Bayesian Approach to Cluster Sampling Under Simple Random Sampling. In *Advances in Statistics-Theory and Applications* (pp. 285-294). Springer, Cham.

Srinivasan, K., Muthu, S., Devadasan, S. R., & Sugumaran, C. (2016). Six Sigma through DMAIC phases: a literature review. *International Journal of Productivity and Quality Management, 17*(2), 236-257.

Tahboub, K. K., & Salhieh, L. (2019). Warehouse waste reduction level and its impact on warehouse and business performance. *Industrial and Systems Engineering Review, 7*(2), 85-101.

Tam, V. W., & Tam, C. M. (2008). Waste reduction through incentives: a case study. *Building Research & Information*, *36*(1), 37-43.

Thomas, A. J., Francis, M., Fisher, R., & Byard, P. (2016). Implementing Lean Six Sigma to overcome the production challenges in an aerospace company. *Production Planning & Control, 27*(7-8), 591-603.

Valamede, L. S., & Akkari, A. C. S. (2020). Lean 4.0: A new holistic approach for the integration of lean manufacturing tools and digital technologies. *International Journal of Mathematical, Engineering and Management Sciences, 5*(5), 851.

Vollmer, I., Jenks, M. J., Roelands, M. C., White, R. J., van Harmelen, T., de Wild, P., ... & Weckhuysen, B. M. (2020). Beyond mechanical recycling: Giving new life to plastic waste. A*ngewandte Chemie International Edition, 59*(36), 15402-15423.

Yadav, G., & Desai, T. N. (2016). Lean Six Sigma: a categorized review of the literature. *International Journal of Lean Six Sigma, 7*(1), 2-24.

Yadav, N., Shankar, R., & Singh, S. P. (2022). Cognitive aspects of lean six sigma. *Quality & Quantity, 56*(2), 607-666.

Zekhnini, K., Cherrafi, A., Bouhaddou, I., Benghabrit, Y., & Garza-Reyes, J. A. (2020). Supply chain management 4.0: a literature review and research framework. *Benchmarking: An International Journal, 28*(2), 465-501.