THE FACTORS INFLUENCING ON PRACTICING AND SUSTAINING LEAN IN APPAREL AND TEXTILE INDUSTRY OF SRI LANKA

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Degree of Master of Science in Business Statistics

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DECLARATION OF THE CANDIDATE

"I declare that this is my own work and this thesis/ dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text"

…………………. …………………..

V.T.Balasooriya Date

DECLARATION OF THE SUPERVISOR

"The above candidate has carried out research for the Master Thesis/ Dissertation under my supervision"

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ABSTRACT

Apparel and Textile Industry is the key contributor in Sri Lankan economy and the industry faces many operational, business and economic challenges time to time. In order to overcome those challenges and to increase the operations excellence, many companies have adapted "Lean" methodologies. Lean Manufacturing is a systematic approach to identify and eliminate waste in the entire value chain. This research was conducted to identify the factors influencing on practicing and sustaining Lean in apparel and textile companies. Seventeen variables were identified as observed variables from literature review. A survey questionnaire was used to collect data from apparel and textile organizations who have implemented Lean. Exploratory Factor Analysis with two extraction methods (PCF, PAF) and three rotation methods (Varimax, Equamax, Quartimax) were carried out to identify major factors influence on lean practices and all the reliability and validity checks were conducted before the Factor Analysis. Four major factors were identified in the results and Principal Component Factoring and Varimax rotation used to define the final solution. Management infrastructure, Waste elimination, Process Improvement through knowledge enhancement and Organization culture were identified as four major factors influence on practicing and sustaining Lean.

Key Words: Factor Analysis, Lean Manufacturing, Operations Excellence, Principal Component Factoring.

This report is dedicated to my parents.

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
JIT	Just In Time
KPI	Key Performance Indicators
PMS	Performance Management Systems
CII	Continuous Improvement Infrastructure
SPC	Statistical Process Control
TPS	Toyota Production Systems
TQM	Total Quality Maintenance
TPM	Total Productive Maintenance
VSM	Value Stream Mapping
CFM	Continuous Flow Management
WCM	World Class Manufacturing
WIP	Work In Progress
SME	Small and Medium Enterprises
EFA	Exploratory Factor Analysis
PCF	Principal Component Factoring
PAF	Principal Axis Factorin

CHAPTER 1

INTRODUCTION

1.1 Overview of Sri Lankan Apparel Industry

Sri Lankan Apparel industry has become a key player in developing the economy in a significant and dynamic way. As per the Export Development Board, the apparel industry has contributed to 42 percent of the total exports of the country as of 2017. The industry has enjoyed epic growth levels over the past four decades and is today Sri Lanka's primary foreign exchange earner accounting to 40 percent of the total exports and 52 percent of industrial products exports. (Sri Lanka Export Development Board, 2017). Figure 1.1 shows the percentage of apparel contribution to total merchandise exports.

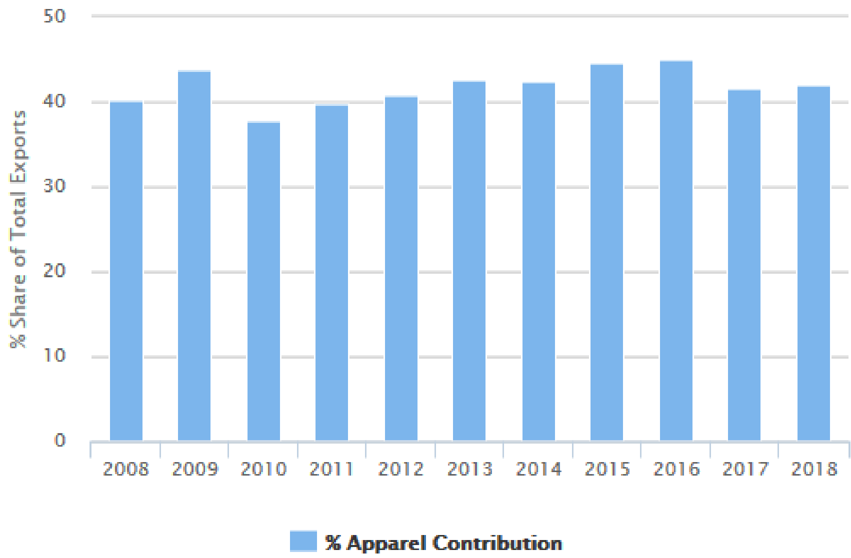


Figure 1.1: Apparel Contribution to Total Merchandise Exports during 2008-2018

Source:(http://www.srilankabusiness.com/apparel/apparel-export-performance.html)

The apparel and textile industry is considered to be the largest single employer in the manufacturing industry. It has provided approximately 300,000 direct employments and approximately 600,000 indirect employments to Sri Lankan citizen. “Around 350 garment factories are opened in different parts of the country, while around 16 textile and fabric manufacturing units are opened in operation”. Sportswear, lingerie, loungewear, swim wear, work wear and casual wear are main product categories in the apparel business (Sri Lanka Export Development Board, 2017). Objective of the organizations in this industry is to produce a range of high quality garments to their customers within the given timeline. These products belong to popular international brands such as Victoria’s Secret, Gap, Nike, Pink, Triumph, Speedo, Marks & Spenser. Materials are sourced and manufactured in Sri Lanka with the highest quality. Sri Lanka is also recognized as the South Asia’s Fashion and Logistics hub and also as producer of “Garments without Guilt” (Sri Lanka Export Development Board, 2017).

Many organizations in the apparel sector got affected with the removal of Multi-Fiber Agreement in 2005 (Silva, Perera, & Samarasinghe, 2011). The major challenges faced by apparel manufacturers are delivering high quality garments at low cost in shortest lead times. Even though this industry provides employment opportunities and act as the key player of building Sri Lankan economy, there is a high business risk. As the business evolves customer expectations change with time. Financial crisis occurred in 2007-2008 and most of the apparel manufacturing industries got affected due to that issue including Sri Lankan companies. Customers increased their demand for low cost garments but the suppliers on the other hand refused to deliver low cost garments. Because of high cost factor in Sri Lanka, most of the companies faced difficulties in getting orders and some companies had to shut down their manufacturing firms (Silva, Perera, & Samarasinghe, 2011). There was a new management change in Victoria’s Secret in 2016 and the business strategies changed according to the new management.

Sri Lankan apparel companies are seeking ways to minimize their operations cost to meet the competition by other low-cost countries such as China, Indonesia and Bangladesh and to survive (Silva, Perera, & Samarasinghe, 2011). Apparel manufacturing companies have very complex operations and processes & it is highly labor intensive and skill based industry (Silva, Perera, & Samarasinghe, 2011) which contains lot of wastes. To minimize or eliminate waste, most of the local apparel manufacturers have adapted different philosophies and strategies and "Lean Manufacturing" is one of the techniques that is getting popular among local apparel manufacturers. Lean manufacturing can be defined as "A systematic approach to identify and eliminate waste through continuous improvement by flowing the product at the demand of the customer." (Womack, Jones, & Ross, 1990). Lean is also a performance measurement method in operations. It is important for decision making as well. Lean is also an integrated set of principles, tools and techniques designed to address the root causes of operations underperformance. It is a systematic approach to eliminate the sources of loss from entire value streams to close the gap between actual performance and the requirements of customers and shareholders.

1.2 Main Areas in Lean

Lean is derived from Toyota Production System which was a pull based manufacturing system. Lean focuses on three main areas availability, flexibility and variability (Pushpakumara, 2017). Availability consists of material, right people, right information, reliable equipment. Flexibility consists of how fast an organization can change one business model to another or one product to another. Variability consists of quality and process capability which includes statistical process control, six-sigma. Six-sigma is a data driven approach and methodology for eliminating defects. (Pushpakumara, 2017). It is essentially a way of organizing and involving the whole organization, every department, every activity, every single person at every level to build a quality centric organization. There are varieties of problems related to product quality and productivity in industries due to varying degrees of abnormality and inefficiency which ultimately causes rejection. Root-cause identification for quality-related problems is a key and necessary step in the operations of manufacturing processes, especially in high throughput automated processes. The top management used to adopt Lean techniques to derive long term business strategies. As per the views of the Lean consultants in Sri Lanka, minimal efforts have been made to establish proper Lean metrics in most of the apparel factories. (Pushpakumara, 2017)

1.3 Lean Practices in Sri Lankan Apparel Industry

Leading apparel and textile manufacturing organizations in Sri Lanka have engaged in researches on Lean management and the leadership teams of these organizations have visited to Toyota in Japan to observe and study this methodology. They identified the possibilities of inculcating Lean into their business and improve efficiency in their processes. “Lean was first implemented as an improvement method at MAS Intimates Linea Clothing Pallekale in 2005” (Gunarathne & Kumarasiri, 2017). Companies like Brandix and Hirdaramani have also tried to implement Lean in their manufacturing processes to minimize waste.

It is well known that 5S acts as the foundation of Lean, “5S stands for Sort (Seiri), Set (Seiton), Shine (Seiso), Standardize (Seiketsu) and Sustain (Shitsuke). Value Stream Map (VSM), Takt time, One Piece Flow, Single Minute Exchange of dies, Kaizen and pull system are the most common tools utilized in the Sri Lankan context for implementation Lean” (Gunarathne & Kumarasiri, 2017). Most of the organizations tried to absorb the Toyota Production Systems (TPS) philosophy to their business directly rather than understanding the real concept behind it. Outsourcing companies, banks, health-care industries and other manufacturers like plastic, tile, rubber and food also started to learn this concept after witnessing the performance shown in the apparel industry after implementing Lean (Pushpakumara, 2017). However, many organizations do research and talk about Lean, only few have sustained Lean practices. In fact, most of the Lean experts say that Lean is a never ending journey.

1.4 Background of the Study

Lean manufacturing concept was introduced to Sri Lanka in the recent past. Most of the organizations are still researching on implementing Lean to minimize waste. There are few research work carried out on its sustainability in Sri Lankan context. Lean is a system or practice which continually search for and eliminate waste throughout the total enterprise and value chain. It considers every enterprise activity as an operation and applies its waste reduction concepts to each activity to achieve enterprise performance. Most of the organizations tried to adapt the Toyota Production Systems (TPS) concept directly to their processes. TPS mainly consists of below key areas. (Pushpakumara, 2017)

- JIT (Just In Time) - Just in Time consists of pull system where the process only produce when necessary. Reduce the process times, cycle time and produce the demand in the shortest time with good quality, quick change over and preventive maintenance are Just in Time techniques.
- Jidoka (Autonomation) - Autonomation is Automation with human thinking. That is building new machineries in such a way that those would stop and notify when an abnormality occurs. It's also an important technique in Lean.
- Standardized work - The processes and the activities were standardized using process maps, standard operation procedures and standard work instructions in a way such that all the steps in a process is defined with responsibilities and standard times. This is also an important tool in Lean.
- Involvement of people - Employees at all levels, managers to ground level employees are involving in generating new improvement ideas, Front line staff also engaged in real improvement activities. This is also a variable to be considered in sustaining Lean practices.
- Absolute Waste Elimination - Seven types of wastes should be identified and an elimination plan or minimizing plan should be in place to build or sustain Lean practices in an organization. Waste has seven major forms as below.

1. Over production: processing sooner, faster or greater quantities than internal and external customers' demand.
2. Over processing: processing beyond the standard required by the customer.

3. Waiting: people or machines which wait for the completion of another work cycle.
4. Inventory: raw material, work in progress or finished goods not having value added. Inventory is a cost.
5. Rework: repetition or correction of a process
6. Motion: unnecessary movement of people or machines within a process.
7. Transportation: unnecessary movement of people or goods between processes.

- TPM (Total Productive Maintenance), TQM (Total Quality Management)
- 5S

In addition to the above, Lean requires the integration of below elements as well.

- Operations Framework: A standard framework to drive the business or processes in an organization should be in place. This includes what is the business, who will be the stakeholders, what are the long term and short term goals, etc. (Kovacheva A. V., 2010)
- Policy Deployment methodologies and KPIs: Once the goals were defined there should be method to deploy policies and goals should cascade down to process level performance indicators. (Pushpakumara, 2017)
- Organization Structure: The structure of the management in an organization should be defined clearly with standard job profiles with responsibilities. Processes or operations should be clearly defined with responsibilities and should be reviewed time to time. (Kovacheva A. V., 2010)
- Performance Management Systems: A Performance Management System should be in place to capture the improvements of people as well as processes and there should be a standard mechanism to reward and recognize the talents of people. (Pushpakumara, 2017)
- Continuous Improvement Infrastructure: A Continuous Improvement Infrastructure should be in place for a successful Lean practicing company where employees continuously think of improvements which can be done to their operations and processes in order to increase the efficiency and

productivity through a suggestion culture or kaizen. (Rahani & Muhammad , 2012)

- Process of developing Operational skills: A process to develop the operations skills of the employees need to be in place where there will be trainings or other initiatives to sharpen their skills and performances. (Abdul Wahab, Mukhtar, & Sulaiman, 2013)
- Management of Key Functional Processes: Key Functional Processes should be identified in an organization and should give a special attention to those processes to achieve maximum output from those special or critical processes. (Pushpakumara, 2017)
- Statistical process control: Control charts were used to interpret data using control limits according to sigma levels. Stability of a process is visualized using control charts and decisions were taken using control charts. Improvement decisions can be made or reducing non value adding activities or defects can be decided using control charts. (Rahani & Muhammad , 2012)
- Value Stream Mapping: End to end process is mapped with process steps, time taken to complete each step, number of employees involving in doing the process. Brainstorming sessions should be taken place with the teams to identify best practices, improvement methods to reduce cycle time or number of steps taken to complete a process (Rahani & Muhammad , 2012)
- Error Proofing: This defines as whatever the initiatives taken to protect the system or machine from human mistakes. This refers to the thoughtful use of devices which eliminates operator’s careless mistakes and also known as Poka-Yoke in Lean and these practices should be in place to sustain Lean in an organization. (Rahani & Muhammad , 2012)
- Problem Solving Techniques: This is an individual and collaborative process and effort in order to manage a situation accurately and take preventive actions based on the analysis. Brainstorming, multi voting, cause and effect diagram, why-why analysis and PDCA (Plan-Do-Check-Act) are commonly using problem solving techniques in Lean. (Pushpakumara, 2017)
- Lean Management Trainings: Employees at all levels need to be given the trainings time to time according to a schedule and the progress need to be

tracked in their activity performance and the efficiencies. The employees who involve in doing new improvements need to be rewarded and recognized by the organization to sustain Lean practices. (Pushpakumara, 2017)

1.5 Importance of the Study

Some of the Lean practices used in most of the organizations are value stream mapping (VSM), operation framework, kaizen/ continuous improvement, error proofing (poka yoke), 5S practices, visual control, problem solving, brainstorming, Fishbone diagrams, pareto analysis, quick change over, kanban, diagnosis of 7 types of wastes (Gunarathne & Kumarasiri, 2017). Anything that does not add value to the end customer is a waste. Waste only adds time and cost and there are seven types of wastes in any organization (Pushpakumara, 2017). The purpose of Lean is to identify those types of wastes and minimize or eliminate those. The research problem is therefore, "What are the key factors influencing on practicing and sustaining Lean in apparel and textile industry Sri Lanka?" The importance of this study is, the organization can identify most influencing factors for Lean practices and they can work to improve those factors to achieve high throughput, variety of products and achieve high profits with a minimum cost, lead time and highest quality. The findings of the study are generally important to all level of management of apparel industry. It will enable the middle level and lower level managers to compare the performance and take measures of improvements where necessary. They can identify what needs to be improved in order to increase the productivity. Operation decisions can be taken to achieve their daily production or service level targets. Top management would be benefitted with the ability to make right decisions in the future, with the awareness of the current success rate with regards to Lean initiatives. The bottom level or operational level workers would be benefitted with continuous improvement culture where they would be recognized for the good initiatives and improvement ideas. New way of thinking would help them to increase the efficiency and productivity of their day to day operations. This type of organization culture will keep the employees satisfied and happy and the attrition would be less. The overall reduction in defects or cost and increase of profits of the organization will indirectly benefit the workers through financial means such as reward and recognition.

Benefits of practicng Lean are considered as:

- Maximize output at the desired time
- Optimize the utilization of people and assets.
- Reduce production cost, lead time and inventories.
- Enhance continuous improvement culture

1.6 Objectives of the study

On overview of the above information, the objective of this study is to identify the factors influencing on practicing and sustaining Lean in apparel and textile sector. This research will assist the apparel and textile organizations to find out the key factors influence on practicing and sustaining Lean culture to achieve excellence.

1.7 Outline of the Study

Sri Lankan apparel industry is the most dynamic and significant contributor for Sri Lanka's economy. Due to the business and economic changes this industry faced many challenges. Lean manufacturing is a technique which supports these organizations to achieve their targets, to increase productivity and quality, to reduce cost by eliminating waste. The purpose of this research is to identify most influencing factors on practicing and sustaining Lean.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Lean

Lean is derived from Toyota Production System which was a pull based manufacturing system. Before TPS in place there were so many other initiatives taken to introduce standard interchangeable parts, time study and standardized work, motion study and invented process charting, psychological mix, statistical quality control. The concept of Just in Time was introduced by Henry Ford starting about 1910. But there was a minor fault in the Ford system as it was the management who did the thinking and the workers did as they were told (Kovacheva A. V., 2010). This caught the attention of Japanese and they studied American production methods including Ford practices and statistical quality control practices of Ishikawa, Edwards Deming, and Joseph Juran and set the foundation of Toyota Production systems. Sakichi Toyoda invented a weaving loom in 1902 which was able to stop when it detected a broken thread and it was the foundation to Autonomation. Quality and respect for their people became very important to Toyota and they also listened and developed the concept of Just In Time together with Autonomation (Jidoka) and these formed the main two pillars of the fledgling Toyota Production System (TPS). (Pushpakumara, 2017). Toyota Production System is shown in Figure 2.1 below.

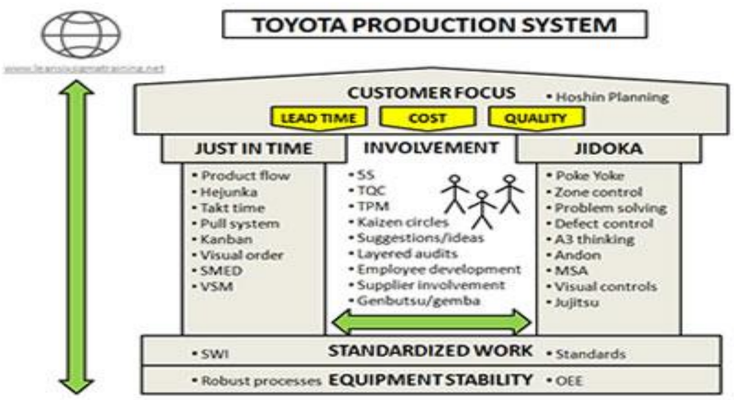


Figure 2.1: World Class Toyota Manufacturing.
Source :(https://www.pinterest.com/pin/453737731177055440/)

From Ford systems, they saw how production lines worked and how processes could be broken down into management steps. They also discovered processes and ideas such as CANDO (clean-up, arrange, neatness, discipline, ongoing improvements) which became the basis for 5S system (A Brief History of Lean Manufacturing). Toyota developed a set of procedures that reduced the time required for set up and changeovers. The development made by Toyota were adapted by other Japanese manufacturing and American companies and named those as Continuous Flow Management (CFM), World Class Manufacturing (WCM) and Stockless Production. "The Machine that Changed the World" by Womack, Jones & Ross was published in 1990 and that is the place where the world was introduced to the term "Lean manufacturing". The purpose of Lean is to minimize waste or non-value adding activities and focus to improve value adding activities in the process. Waste or non – value adding activities could be identified as any activity which absorbs resources but does not create a value to the customer (Pushpakumara, 2017). TPS has identified seven major types of non-value-adding activities as waste in business or manufacturing processes. Even though being identified as elimination of waste, Lean has a total philosophy behind it. Lean is often identified as, developing principles that is right for the organization and diligently practicing those would achieve high performance that continues to add value to customers and society. It is a way of thinking rather than another operations improvement technique (Pushpakumara, 2017).

Most waste is invisible, therefore to identify and eliminate these waste, Lean Manufacturing concept was evolved. Value stream mapping and process mapping are two valuable tools that help to eliminate waste and streamline work. Factories include people and for a proper functioning people and technology must integrate in a system exploiting the strengths and minimizing the limitations of each component. Every core discipline has a psychological component and Eric Trist called this as a "Social-Technical System" (A Brief History of Lean Manufacturing).

2.2 Previous Researches on Lean Manufacturing

Pius Achanga, Esam Shehab & Rajkumar Roy (2006) have done a research to identify critical success factors for Lean implementation within 10 SMEs based in the East of England. Observations study, literature review and personal interviews were used as research methodology to conduct this study. The researchers have identified four major factors which are fundamental and critical for the implementation of Lean manufacturing within SMEs which include leadership and management, finance, skills and expertise, culture of the recipient organization. Out of these four factors, it has been hypothesized that leadership and management commitment are the most critical factors in determining the success of a Lean project within the SMEs.

Rahman, Laosirihongthong & Sohal (2010), have identified 13 Lean practices to measure the successful Lean implementation in manufacturing firms in Thailand. They have gathered data from 187 manufacturing companies in Thailand and have used principal component analysis to identify these practices under three constructs such as JIT, waste minimization/ elimination and flow management. In that research, they have examined the Lean practices and the adoption levels of manufacturing organizations and their operational performance. Operational performance was measured using four parameters such as quick delivery compared to competitors, unit cost of products relative to competitors, overall productivity and customer satisfaction. The results have proved that there is a positive relationship between Lean practices and operational performance. Rahman, Laosirihongthong & Sohal (2010) have further identified waste elimination is a critical factor on successful Lean implementation.

The research of (Hines, Holwe & Rich, 2004) has created an awareness in the managers' vision of evolving towards Lean thinking and developing an understanding about the theoretical underpinning of organization learning (Kovacheva A. V., 2010). Continuous improvement culture was identified as a key element in achieving sustainability in long run. Toyota has followed "4P model- philosophy, process, people and partners and problem solving" of Toyota way (Kovacheva A. V., 2010). Chappell (2002) defined lean thinking as applicable for all aspects of a business and positively impact on not just production operations, but the whole range of business process including product development, design and sales. Lean culture has the function of a role model, which guides the employees through the organizational change towards the value of Lean thinking (Kovacheva A. V., 2010). Lean Enterprise is a group of individuals, functions and legally separated but operationally synchronized companies (Womack, Jones, & Ross, 1990). A.V Kovacheva in 2010 identified that human resource practices, management styles, organizational strategic vision, organizational culture, external partnerships as key success factors that enhance Lean implementation.

Hodge et al. (2011) has found that major issues which would affect to smooth Lean operations are, workers reluctant to give suggestions, training issues and resistant to change. That research was carried out based on 11 garment factories in north and south Carolina, USA (Gunarathne & Kumarasiri, 2017). Silva, Perera & Samarasinghe (2011) have conducted a research to identify the factors affecting for a successful implementation of Lean manufacturing tools and techniques in the apparel industry. They have used the judgmental sampling method to select the sample and have gathered data from 15 apparel companies in Sri Lanka using personal interviews and observational methods. They have found that for a successful implementation of Lean in the apparel industry, few factors are important such as introduction method, order of implementation and implementation method.

Behrouzi and Yew Wong have done a research on Lean performance evaluation of manufacturing systems in a dynamic and innovative approach in 2011. Soriano-Meier and Forrester carried out a survey on more than 30 firms in UK ceramics tableware industry. They relied upon the model developed by Karlsson and Ahlstron that characterizes the principles of Lean production. Nine variables of leanness were identified such as elimination of waste, continuous improvement, zero defects, JIT, pull of materials, multifunctional teams, decentralization, integration of functions and vertical information systems (Behrouzi & Yew Wong, 2011). Wan developed a mathematical model to measure leanness and agility of manufacturing systems. Behrouzi and Yew Wong identified that waste elimination and JIT as most important components of Lean performance. In addition to those two, continuous improvement was identified to be happened at all levels.

“Different researchers have considered different indicators to define and identify the performance and improvement of Lean. Kumar and Sampath. (2012) have identified level of WIP as an indicator of performance and have investigated on how Lean applications such as cellular layout could affect WIP levels” (Gunarathne & Kumarasiri, 2017). They have identified that WIP levels could be reduced approximately by 70 or 80 percent through cellular production layout. That would further reduce the lead time from 2 days to 20 minutes which was a massive saving of both time and effort. Karim et al. (2013) developed a Leanness evaluation metric on the basis of Continuous Performance Measurement (CPM) where they used the effectiveness and efficiency of the production as indicators of performance of an entity.

Rahani AR and Muhammad al-Ashraf conducted a study to identify the use of VSM for production flow analysis in 2012. VSM is one of the key Lean tool to identify the opportunities for various Lean techniques. As VSM involves in all of the process steps, both value added and non-value added were analyzed using VSM as a visual tool to see the hidden waste and sources of waste (Rahani & Muhammad , 2012). It was identified that Standard Operations Procedures (SOP) was the key driver in continuous improvement sustainability on the production floor. Statistical process control, Kaizen (continuous improvement) and Poka-yoke (error proofing) were identified as appropriate tools.

Lack of knowledge and understanding in Lean, culture, skills, age and size of company also contribute to the degree of adoption of Lean tools and techniques (Abdul Wahab, Mukhtar, & Sulaiman, 2013). Abdul Wahab, Mukhtar and Sulaiman researched to identify indicators, practices or tools or techniques for implementation of Lean in manufacturing industry. Their objective was to define a conceptual model for Lean manufacturing. They have obtained seven dimensions that contribute to leanness in manufacturing such as manufacturing process and equipment, manufacturing planning and scheduling, visual information systems, supplier relationships, customer relationships, workforce, product development and technology. Their model also showed how Lean dimensions relate to eight types of waste.

Sundar, Balaji and Satheehkumar have done a research to identify Lean implementation techniques in 2014. For successful Lean implementation, an organization has to focus on VSM, cellular manufacturing, U-line system, line balancing, inventory control, single minute exchange of dies (SMED), pull system, Kanban, production levelling (Sundar, Balaji, & SatheeshKumar, 2014). Based on these factors they have developed a Lean road map for organizations to implement lean manufacturing system.

Gunarathne & Kumarasiri (2017) have also conducted a research to identify the impact of Lean utilization on operational performance. Their research was based on Rahman, Laosirihongthong & Sohal (2010) research and they have also found that waste elimination practices has the more impact on operational performance. Wickramasinghe & Wickramasinghe in 2017 conducted a research on implementation of Lean production practices and manufacturing performance. They have found that waste minimization, continuous improvement, defects minimization, JIT and pull, cross functional teams, employee involvement and information availability have significant, positive relation to manufacturing performance. That research predicted that the simultaneous implementation of these seven Lean production practices resulted in positive manufacturing plant outcomes.

2.3 Limitations of the Previous Researches

Table 2.1: Summary of previous researches, findings and limitations

Name	**Year**	**Research**	**Findings**	**Limitations**
Pius Achanga, Esam Shehab & Rajkumar Roy	2006	critical success factors for Lean implementation	leadership and management finance skills and expertise culture	Lean Tools & Waste Elimination methods were not considered
Rahman, Laosirihongthong & Sohal	2010	Impact of Lean Strategy on Operational Performance	JIT waste minimization/ elimination flow management	Culture and organizational structure were not considered
Hines, Holwe & Rich	2004	Details were taken from A.V.Kovacheva's research	Continuous improvement culture	Lean Tools & Waste Elimination methods were not considered
A.V Kovacheva	2010	Challenges in Lean Implementation: Successful transformation towards lean enterprise	human resource practices management styles organizational strategic vision organizational culture external partnerships	Lean Tools & Waste Elimination methods were not considered
Silva, Perera & Samarasinghe	2011	Factors affecting for a successful implementation of Lean manufacturing tools and techniques in the apparel industry	Introduction method order of implementation implementation method.	Culture and organizational structure, Operation Framework, Performance Management, Lean tools, Waste Elimination methods were not considered
Behrouzi and Yew Wong	2011	Lean Performance Evaluation of Manufacturing Systems: A dynamic and innovative approach	waste elimination JIT continuous improvement	Culture and organizational structure were not considered

Soriano-Meier and Forrester/ Karlsson and Ahlstron		Details were taken from Behrouzi and Yew Wong's research	elimination of waste continuous improvement zero defects JIT, pull of materials multifunctional teams decentralization integration of functions and vertical information systems	Organization culture, unopened ideas were not considered
Kumar and Sampath	2012	Garment Manufacturing through lean initiative- an empirical study on WIP fluctuation in T-shirt production unit	WIP Continuous Performance Measurement	Culture and organizational structure, Operation Framework, Performance Management, Lean tools, Waste Elimination methods were not considered
Rahani AR and Muhammad al-Ashraf	2012	Production Flow Analysis through Value Stream Mapping	VSM Standardized work Statistical Process Control Continuous Improvement Error Proofing	Organization culture, unopened ideas were not considered
Abdul Wahab, Mukhtar and Sulaiman	2013	A Conceptual Model of Lean Manufacturing Dimensions	manufacturing process and equipment manufacturing planning and scheduling visual information systems supplier relationships customer relationships workforce product development and technology Eight types of waste	Organization culture was not considered
Sundar, Balaji and Satheehkumar	2014	A Review on Lean Manufacturing Implementation Techniques	VSM cellular manufacturing, U-line system line balancing inventory control single minute exchange of dies (SMED) pull system Kanban production levelling	Organization culture was not considered

Gunarathne & Kumarasiri	2017	Impact of Lean Utilization on Operational Performance.	waste elimination	Culture and organizational structure, Operation Framework, Performance Management, Lean tools were not considered
Wickramasinghe & Wickramasinghe	2017	Implementation of lean production practices and manufacturing performance : The role of lean duration	waste minimization continuous improvement defects minimization JIT and pull cross functional teams employee involvement information availability	Culture and organizational structure, Operation Framework, Performance Management, Lean tools were not considered

2.4 Significant Variables on Practicing Lean

It was identified that there is a direct relationship between utilization of Lean tools and performance (Kumar & Sampath, 2012). It is also evident that there is a positive relationship between Lean practices and operational performance (Rahman, Laosirihongthong, & Sohal, 2010). Pius Achanga, Esam Shehab & Rajkumar Roy (2006) have identified that leadership and management support is a critical factor in implementing Lean. According to Hodge et al. (2011), main issues affecting for a smooth Lean operation are training issues, resistant to change and reluctant to give suggestions. Introduction methods, order of implementation and implementation methods are factors affecting for a successful implementation of Lean tools and techniques (Silva, Perera, & Samarasinghe, 2011). Gunarathne & Kumarasiri (2017) have also found that waste elimination practices has the most impact on operational performance. Continuous Improvement culture is a must to sustain lean (Hines, Holwe & Rich, 2004). Human resource practices, management styles, organizational strategic vision, culture and external partnerships are critical factors for lean transformation journey (Kovacheva A. V., 2010). VSM, cellular manufacturing, production levelling, Kanban, JIT are important factors for Lean implementation (Sundar, Balaji, & SatheeshKumar, 2014). Waste elimination, continuous improvement, cross functional teams, employee involvement are critical factors for manufacturing performance (Wickramasinghe & Wickramasinghe, 2017).

2.5 Outline of Chapter 2

After going through the literature, operating system which includes operational framework and milestones, management infrastructure which includes organization structure, performance management system, continuous improvement infrastructure, process for developing operational skills, managing key functional support, JIT, standardized work, statistical process control, waste elimination, VSM, Poka-Yoke, problem solving can be considered as most significant and influential variables for Lean practices and sustainability. In addition to the above factors, autonomation behaviour of people which includes involvement of people to generate new ideas and trainings provided to them are also considered in this research as influential variables for Lean practices. These variables were selected from literature to carry out the present study. Furthermore, it was noted that the use of statistics avoid the subjectivity of findings in most of the past studies.

CHAPTER 3

METHODOLOGY

3.1 Research Design

This research was designed to have both qualitative and quantitative approach where the specific observed variables influenced on Lean were identified using literature and previous researches and developed a structural questionnaire to acquire information from employees who practice Lean in apparel and textile industry. The questionnaire is shown in Appendix I. The questionnaire was consisted of dichotomous and likert order questions with some open ended questions. The questionnaire was pre tested using 10 people.

3.2 Sample Size

Sample size determination is a crucial factor in surveys as in any empirical study in which the goal is to make inferences about a population is based on the sample size selected. In general, sample size is determined by the following factors.

i. level of significance
ii. power of the study
iii. size of the population
iv. expected margin of error
v. resources such as time, money, man power

The sample size for this study was determined using equation 3.1, different sample sizes were calculated for the desired levels and the results were shown in Table 3.1.

$$n = \frac{z^2.p.(1-p)}{d^2} \qquad (3.1)$$

where, z = significance level

d = marginal error

p = proportion

As there is no idea on p value, it was taken in a way such that p*(1-p) would be maximized and it is obvious that p*(1-p) is maximized at p=0.5. The sample size required for different values at margin of errors is shown in Table 3.1

Table 3.1: Required Sample Sizes for Different Marginal Errors with 95 percent Confidence

z	p	d	N
1.96	0.5	0.1	96
1.96	0.5	0.08	150
1.96	0.5	0.06	266
1.96	0.5	0.04	600
1.96	0.5	0.02	2401

Based on the time factor and the cost factor, sample size was decided to be 150 with the marginal error of 0.08.

3.2.1 Sampling Frame

As there is no idea about the true population, the sample size was distributed among three companies by considering the number of employees and number of factories practicing Lean.

Table 3.2: Distribution of Sample size

Company	No of employees	Sample size
Brandix	47,000+	40
Hirdaramani	45,000+	35
MAS Holdings	93,000+	75
Total		**150**

In order to get more responses 200 questionnaires were circulated randomly among individuals who work in apparel and textile industry and who practice Lean in their companies.

3.3 Identification of Observed Variables

Based on literature survey, the following 17 variables were identified as factors to be tested.

- Operations Framework
- Policy Deployment Methodologies and Key Performance Indicators
- Organization Structure
- Performance Management Systems
- Continuous Improvement Infrastructure
- Process of Developing Operational Skills
- Management of key Functional Processes
- Just in Time Techniques
- Autonomation
- Standardized Work
- Statistical Process Control
- Diagnosis of Seven Waste
- Value Stream Mapping
- Error Proofing
- Problem Solving Techniques
- Involvement of People on Generating Improvement Ideas
- Lean Management Trainings

3.4 Target Group

As stated previously in section 3.2.1, the questionnaires were only sent to the organizations in the apparel and textile industry who practice Lean through Google forms. The target sample was employees who work as staff, executive, managers, general managers and directors. However, the response rate was very low in the first and second round since very few apparel and textile organizations have adopted Lean. With the support of Institute of Lean Manufacturing, managed to collect 93 responses from MAS Holdings, Hirdaramani and Brandix (Pvt) Ltd. Considering the time and cost factors, it was decided to perform the analysis with existing data of 93 responses even though the targeted sample size was 150. The collected data was validated first by checking the reliability using Cronbach's Alpha test and all the analysis were done using SPSS.

3.5 Tests of Reliability and Validity: Cronbach's Alpha

Cronbach's Alpha is a measure of reliability or internal consistency. It is commonly used when the questionnaire consists of multiple likert questions. It can be written as a number of test items and average inter-correlation among the items. The formula to calculate the standardized Cronbach's Alpha is given in the formula 3.2 below.

$$\propto = \frac{N.\bar{c}}{\bar{v}+(N-1)\ \bar{c}} \qquad (3.2)$$

Where, N = number of items

$\bar{c}$ = average inter-item covariance

$\bar{v}$ = average variance

When number of items increased, the cronbach's alpha value would also get increased. If the average inter-item correlation is low, then alpha value would be also low. Table 3.3 defines the rule of thumb for interpreting alpha levels for dichotomous or likert order questions.

Table 3.3: Alpha Levels and Consistency

Cronbach's alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

Source : (http://www.statisticshowto.com/cronbachs-alpha-spss/)

Therefore, if the cronbach's alpha value is greater than 0.7, the results considered to be acceptable and analysis to be performed.

3.6 Exploratory Factor Analysis (EFA)

EFA is a multivariate statistical analysis method which used for data reduction or structure detection. The purpose of the data reduction is to remove highly correlated variables from the system by replacing that with a smaller number of uncorrelated variables. The purpose of structure detection is to examine the underlying relationships between variables. It detects relationships between correlated variables by examining variance and covariance of the system. EFA is heavily used in analysis survey data on likert scale as it is an efficient statistical tool to detect hidden factors or latent variables using the observed variables. The recommended conditions to carry out factor analysis for likert scale data are,

- High correlation among variables- This indicates that variables can be grouped into homogeneous set of variables.
- Partial correlations controlling other variables should be small compared to the original variables.
- KMO statistic should be greater than 0.6

3.6.1 KMO Test

Kaizer- Meyer- Olkin (Test) is a measurement of sampling adequacy. It is a measurement to check how much a dataset is suitable for Factor Analysis. It measures sample adequacy for each variable in the model and for the complete model. The statistic indicates the proportion of variance in a dataset which might be caused by underlying factors. If the KMO value is closer to 1, that indicates a Factor Analysis is suitable for the dataset. To conduct the Factor Analysis, KMO value should be greater than 0.6. Table 3.3 shows the rule of thumb for interpreting KMO values.

Table 3.4: KMO Values and Recommendations

KMO Indicator	Recommendation
>0.9	Highly recommended
>0.8	Recommended
>0.6	Reasonable to consider
<0.6	Not Recommended

3.6.2 Bartlett's Test

It tests the hypothesis that the true correlation matrix is not significantly different from the identity matrix, which would indicates that the variables are unrelated (H_0: $\sum = 1$ vs H_1: $\sum \neq 1$) and therefore, unsuitable for structure detection. It is required that there should be a high significance correlation among variables. The null hypothesis need to be rejected to satisfy the Factor Analysis requirement. Small values which are less than 0.05 of the significance level indicates that a Factor Analysis would be suitable to conduct with the data.

3.6.3 Factor Extraction Methods

There are so many methods used to extract factors in Factor Analysis, among those the most popular factor extraction methods for likert scale data are Principal Component Factoring (PCF) and Principle Axis Factoring (PAF). Thus, in this study, only PCF and PAF were performed since all the observed variables are categorical.

- Principal Component Factoring (PCF) – In PCF, it is assumed that the communalities for all the variables are equal to one and no prior estimate is required for communalities. It is assumed that few components which eigen value is greater than one, would account for the majority of the observed variance in the system. These principal components would be considered as common factors and remaining principal components would be considered as nuisance components.
- Principal Axis Factoring (PAF) – In PAF, communalities would be estimated. The initial communalities are considered as the squared multiple correlation that each variable has with the other response variables. PAF method is also a descriptive procedure and both PAF and PCF can be used when the assumption of normality has been violated.

3.6.4 Factor Rotation Methods

For the purpose of the interpretation, factors would be rotated using orthogonal transformation. In orthogonal rotations it is assumed that the factors are independent and uncorrelated with each other. Rotation procedures try to make some factor loadings close to zero and other factor loadings large. The rotation procedures keep the factors uncorrelated as the initial factors are also orthogonal. The popular rotation techniques are Varimax, Quartimax and Equamax. It is necessary to check whether the underlying factors are invariant of the type of rotation or else the results from Varimax rotation would be considered as the final result. Benefits of the Varimax rotation is that it maximizes the variances of the loadings within the factors while maximizing differences between high and low loadings on a particular factor. Quartimax is good for detecting overall factor. It maximizes the squared loadings so that, each item loads most strongly onto a single factor. Equamax is a hybrid of Varimax and Quartimax.

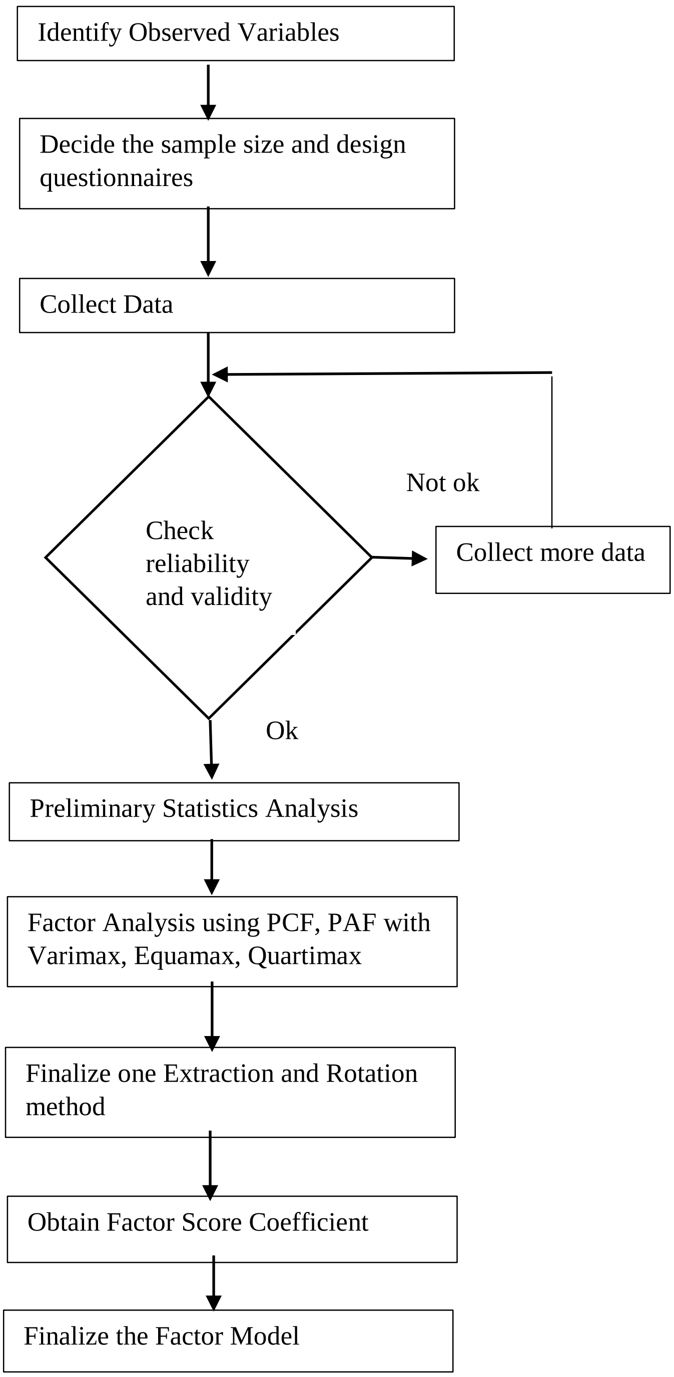
3.6.5 Interpretation of Factors

The factor score coefficients are not unique and can depend on the type of rotation or type of extraction. A rule of thumb used by most of the analysts is that factor loadings greater than 0.5 in absolute value are considered to be significant. A single significant loading for each variable on only one factor across each row. If there were variables that failed to load significantly on any factor, those should critically evaluate and should consider of deriving a new factor solution after eliminating those. Once all the significant loadings were identified, some meaning should be assigned to those factors based on the patterns of the loadings. The larger the absolute size of the factor loading for a variable, the more important is the variable in interpreting the factor. The sign of the loadings also need to be considered in labelling the factors.

Generally, factors need to be invariant of the factor extraction method as well as the factor rotation method. If it is not invariant, the results under PCF and varimax are used to interpret results.

The following figure 3.1 summarize the flow chart of the steps in data collection and data analysis.

3.7 Steps of Conducting the Study



(Figure 3.1: Steps of Conducting the Analysis)

CHAPTER 4

EXPLANATORY DATA ANALYSIS

4.1 Response Rate and Reliability of Data

93 responses were obtained from the questionnaires.

4.1.1 Response Rate

The response rate varies from 53 percent (Brandix) to 69 percent (MAS Holdings) with the overall response rate of 62 percent. The response rate of the three companies is shown in the Table 4.1

Table 4.1: Sample Statistics

Company	Distribution	Response	Response rate
Brandix	40	21	53%
Hirdaramani	35	20	57%
MAS Holdings	75	52	69%
Total	150	93	62%

Highest number of responses were obtained from MAS Holdings which covers 56 percent of the sample out of 93 responses. Brandix and Hirdaramani cover approximately 20 percent each for the sample out of 93 responses. Dispersion of the sample is clearly shown in the Figure 4.1

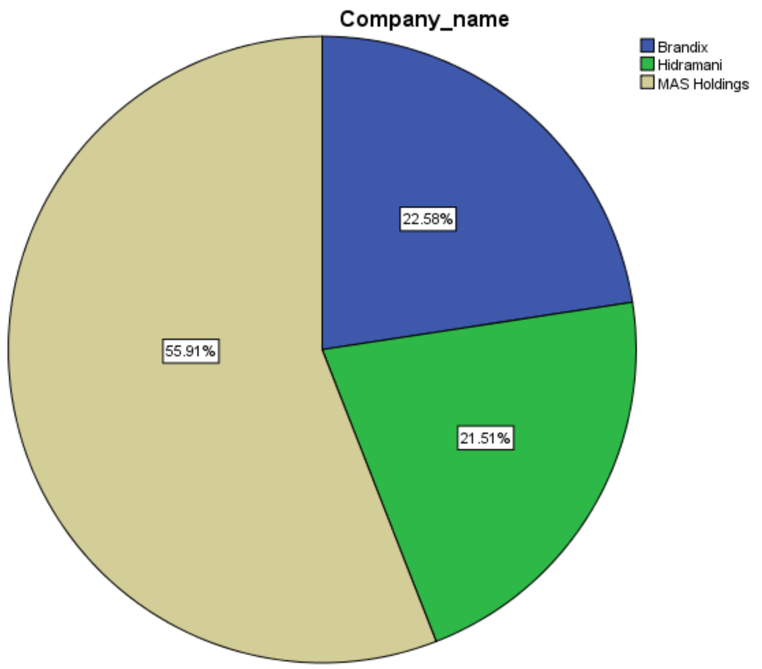


Figure 4.1: Sample Dispersion

4.1.2 Reliability of Data

Cronbatch's Alpha test was performed to check the reliability and validity of the questionnaire since all the questions are in dichotomous and likert order. The results are shown in Table 4.2.

Table 4.2: Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.945	.948	18

Cronbach's Alpha value is 0.945 (greater than 0.7). Therefore, the reliability of the questionnaire is really high and data set can be used to derive good conclusions.

4.2 Descriptive Statistics of the Response Variables

4.2.1 Level of Practicing Lean

Table 4.3: Level of Practicing Lean

Level	Frequency	Percent	Cumulative Percent
1	4	4.3	4.3
2	12	12.9	17.2
3	27	29.0	46.2
4	37	39.8	86.0
5	13	14.0	100.0
Total	93	100.0	

(Level 1- Poorly practicing, 5-Highly practicing)

According to Table 4.3, 29 percent of the sample have responded that they are moderately practicing Lean in their companies. 39.8 percent of the sample have responded that they are practicing Lean in a good level. Only 14 percent have responded that they are highly practicing Lean. Therefore, we can consider that 54 percent of the sample is practicing Lean in a good level and the coverage is good to derive conclusions.

Table 4.4: Descriptive Statistics of Practicing Lean

Q1	Mean	Median	Mode	Q3
3.00	3.46	4.00	4	4.00

Mean value is 3.46 and median and mode values are at 4 which means most of the people have responded that their companies are practicing Lean in a good level. 25 percent to 75 percent responses were lying within 3 to 4 (Moderate to Good).

4.2.2 Level of Influence of Operations Framework on Lean

Table 4.5: Level of Influence of Operations Framework on Lean

Level		Frequency	Percent	Cumulative Percent
Valid	2	1	1.1	1.1
	3	22	23.7	24.7
	4	57	61.3	86.0
	5	13	14.0	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.5, 61 percent of the sample has responded that the influencing level is good. 14 percent has responded that the influencing level is high. Therefore, 75 percent has responded that the influencing level of operations framework on Lean Management is good and high. 24 percent has responded that the level of influence is moderate.

4.2.3 Level of Influence of Policy Deployment and KPI on Lean

Table 4.6: Level of Influence of Policy Deployment and KPI on Lean

Level		Frequency	Percent	Cumulative Percent
Valid	2	1	1.1	1.1
	3	20	21.5	22.6
	4	57	61.3	83.9
	5	15	16.1	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.6, 61 percent of the sample has responded that the influencing level is good. 16 percent has responded that the influencing level is high. Therefore, 77 percent has responded that the influencing level of Policy Deployment and setting up Key Performance Indicators (KPI) on Lean Management is good and high. 22 percent has responded that the level of influence is moderate.

4.2.4 Level of Influence of Organization Structure on Lean

Table 4.7: Level of Influence of Organization Structure on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	1	1	1.1	1.1
	2	2	2.2	3.2
	3	34	36.6	39.8
	4	53	57.0	96.8
	5	3	3.2	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.7, 57 percent of the sample has responded that the influencing level is good. 3 percent has responded that the influencing level is high. Therefore, 60 percent has responded that the influencing level of Organization Structure on Lean Management is good and high. 37 percent has responded that the level of influence is moderate.

4.2.5 Level of Influence of PMS on Lean

Table 4.8: Level of Influence of PMS on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	1	1	1.1	1.1
	2	5	5.4	6.5
	3	37	39.8	46.2
	4	48	51.6	97.8
	5	2	2.2	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.8, 52 percent of the sample has responded that the influencing level is good. 2 percent has responded that the influencing level is high. Therefore, 54 percent has responded that the influencing level of a Performance Management System on Lean Management is moderately good. 40 percent has responded that the level of influence is moderate.

4.2.6 Level of Influence of CII on Lean

Table 4.9: Level of Influence of CII on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	1	1	1.1	1.1
	2	1	1.1	2.2
	3	10	10.8	12.9
	4	65	69.9	82.8
	5	16	17.2	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.9, 70 percent of the sample has responded that the influencing level is good. 17 percent has responded that the influencing level is high. Therefore, 87 percent has responded that the influencing level of Continuous Improvement Infrastructure on Lean Management is good and high. 11 percent has responded that the level of influence is moderate.

4.2.7 Level of Influence of Developing Operations Skills on Lean

Table 4.10: Level of Influence of Developing Operations Skills on Lean Management

Level		Frequency	Percent	Cumulative Percent
	2	1	1.1	1.1
	3	35	37.6	38.7
Valid	4	55	59.1	97.8
	5	2	2.2	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.10, 59 percent of the sample has responded that the influencing level is good. 2 percent has responded that the influencing level is high. Therefore, 61 percent has responded that the influencing level of Developing Operations Skills on Lean Management is moderately good. 38 percent has responded that the level of influence is moderate.

4.2.8 Level of Influence of Management of Key Functional Processes on Lean

Table 4.11: Level of Influence of Management of Key Functional Processes on Lean

Level		Frequency	Percent	Cumulative Percent
Valid	2	3	3.2	3.2
	3	40	43.0	46.2
	4	50	53.8	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.11, 54 percent of the sample has responded that the influencing level is good. 43 percent has responded that the level of influence is moderate.

4.2.9 Level of Influence of JIT on Lean

Table 4.12: Level of Influence of JIT on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	2	1	1.1	1.1
	3	1	1.1	2.2
	4	50	53.8	55.9
	5	41	44.1	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.12, 54 percent of the sample has responded that the influencing level is good. 44 percent has responded that the influencing level is high. Therefore, 98 percent has responded that the influencing level of JIT on Lean Management is very high.

4.2.10 Level of Influence of Autonomation on Lean

Table 4.13: Level of Influence of Autonomation on Lean Management

Level		Frequency	Percent	Cumulative Percent
	2	4	4.3	4.3
	3	23	24.7	29.0
Valid	4	62	66.7	95.7
	5	4	4.3	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.13, 67 percent of the sample has responded that the influencing level is good. 4 percent has responded that the influencing level is high. Therefore, 71 percent has responded that the influencing level of Autonomation on Lean Management is good.

4.2.11 Level of Influence of Standardized Work on Lean

Table 4.14: Level of Influence of Standardized Work on Lean Management

Level		Frequency	Percent	Cumulative Percent
	2	1	1.1	1.1
	3	4	4.3	5.4
Valid	4	48	51.6	57.0
	5	40	43.0	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.14, 52 percent of the sample has responded that the influencing level is good. 43 percent has responded that the influencing level is high. Therefore, 95 percent has responded that the influencing level of Standardized Work on Lean Management is high.

4.2.12 Level of Influence of Statistical Process Control

Table 4.15: Level of Influence of SPC on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	2	1	1.1	1.1
	3	5	5.4	6.5
	4	53	57.0	63.4
	5	34	36.6	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.15, 57 percent of the sample has responded that the influencing level is good. 37 percent has responded that the influencing level is high. Therefore, 94 percent has responded that the influencing level of Statistical Process Control on Lean Management is high.

4.2.13 Level of Influence of Diagnosis of Seven Waste on Lean

Table 4.16: Level of Influence of Diagnosis of Seven Waste on Lean

Level		Frequency	Percent	Cumulative Percent
Valid	2	2	2.2	2.2
	3	1	1.1	3.2
	4	48	51.6	54.8
	5	42	45.2	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.16, 52 percent of the sample has responded that the influencing level is good. 45 percent has responded that the influencing level is high. Therefore, 97 percent has responded that the influencing level of Diagnosis of Seven Waste on Lean Management is high.

4.2.14 Level of Influence of VSM on Lean

Table 4.17: Level of Influence of Value Stream Mapping on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	2	3	3.2	3.2
	3	37	39.8	43.0
	4	44	47.3	90.3
	5	9	9.7	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.17, 47 percent of the sample has responded that the influencing level is good. 10 percent has responded that the influencing level is high. Therefore, 57 percent has responded that the influencing level of Value Stream Mapping on Lean Management is good. 40 percent has responded that the influence level is moderate.

4.2.15 Level of Influence of Error Proofing on Lean

Table 4.18: Level of Influence of Error Proofing on Lean Management

Level		Frequency	Percent	Cumulative Percent
Valid	2	2	2.2	2.2
	3	29	31.2	33.3
	4	56	60.2	93.5
	5	6	6.5	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.18, 60 percent of the sample has responded that the influencing level is good. 7 percent has responded that the influencing level is high. Therefore, 67 percent has responded that the influencing level of Error Proofing on Lean Management is good. 31 percent has responded that the influence level is moderate.

4.2.16 Level of Influence of Problem Solving on Lean

Table 4.19: Level of Influence of Problem Solving Techniques on Lean Management

Level		Frequency	Percent	Cumulative Percent
	2	1	1.1	1.1
	3	21	22.6	23.7
Valid	4	61	65.6	89.2
	5	10	10.8	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.19, 66 percent of the sample has responded that the influencing level is good. 11 percent has responded that the influencing level is high. Therefore, 77 percent has responded that the influencing level of Problem Solving Techniques on Lean Management is high. 23 percent has responded that the influence level is moderate.

4.2.17 Level of Influence of People Engagement on Lean

Table 4.20: Level of Influence of People Engagement on Lean Management

Level		Frequency	Percent	Cumulative Percent
	2	3	3.2	3.2
	3	23	24.7	28.0
Valid	4	63	67.7	95.7
	5	4	4.3	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.19, 68 percent of the sample has responded that the influencing level is good. 4 percent has responded that the influencing level is high. Therefore, 72 percent has responded that the influencing level of People Engagement on Lean Management is high. 25 percent has responded that the influence level is moderate.

4.2.18 Level of Influence of Trainings on Lean

Table 4.21: Level of Influence of Lean Training on Lean Management

Level		Frequency	Percent	Cumulative Percent
	2	2	2.2	2.2
	3	7	7.5	9.7
Valid	4	69	74.2	83.9
	5	15	16.1	100.0
	Total	93	100.0	

(Level 1- Poorly influencing, 5-Highly influencing)

According to Table 4.21, 74 percent of the sample has responded that the influencing level is good. 16 percent has responded that the influencing level is high. Therefore, 90 percent has responded that the influencing level of Lean Training on Lean Management is high. 8 percent has responded that the influence level is moderate.

4.2.19 Level of Productivity Increase through Lean Practices

Table 4.22: Level of Productivity Increase by Lean Practices

Level		Frequency	Percent	Cumulative Percent
	21%-40%	12	12.9	12.9
	41%-60%	57	61.3	74.2
Valid	61%-80%	21	22.6	96.8
	81%-100%	3	3.2	100.0
	Total	93	100.0	

According to Table 4.22, 61 percent has responded that Productivity in an organization would be increased by 41 percent to 60 percent through effective Lean practices. 23 percent has responded that the productivity increase would be 61 percent to 80 percent through effective Lean practices.

4.3 Summary of Chapter 4

Reliability of the questionnaire was very high for the observed variables. Preliminary statistics analysis was done to the observed variables and the mean values were closer to 4 for most of the variables (Table 4.23). This indicates that most of the respondents have rated that influence level of these variables to Lean practices and sustainability is high. 64 percent has responded that productivity level would be increased by 41 percent to 60 percent through Lean practices.

Table 4.23: Descriptive Statistics of the Sample

Variable	Mean	Median	Mode	Q1	Q3
Ops_Framework	3.88	4.00	4	3.50	4.00
Policy_Deploy	3.92	4.00	4	4.00	4.00
Org_Structure	3.59	4.00	4	3.00	4.00
PMS	3.48	4.00	4	3.00	4.00
CII	4.01	4.00	4	4.00	4.00
Ops_skill_dev	3.62	4.00	4	3.00	4.00
Management_key_functions	3.51	4.00	4	3.00	4.00
JIT	4.41	4.00	4	4.00	5.00
Autonomation	3.71	4.00	4	3.00	4.00
Standardized_work	4.37	4.00	4	4.00	5.00
SPC	4.29	4.00	4	4.00	5.00
Seven_Waste	4.40	4.00	4	4.00	5.00
VSM	3.63	4.00	4	3.00	4.00
Error_Proof	3.71	4.00	4	3.00	4.00
Problem_Solving	3.86	4.00	4	4.00	4.00
People_eng	3.73	4.00	4	3.00	4.00
Lean_Training	4.04	4.00	4	4.00	4.00

Mode of each variable is 4 for all observed variables. 25 percent to 75 percent responses were observed within 3 to 5 categories, which implies that the influence level is moderate to high. Thus, it can be concluded that majority of the respondents agree to the fact that all the variables are supporting for Lean Practices. This can be further justified using percentages of Table 4.24.

Table 4.24: Percentages of Observed Variables According to the Level of Agreement

Observed Variables	**1**	**2**	**3**	**4 & 5**
Ops Framework	0%	1%	24%	75%
Policy Deployment	0%	1%	22%	77%
Org Structure	1%	2%	37%	60%
PMS	1%	5%	40%	54%
CII	1%	1%	11%	87%
Development of Ops skills	0%	1%	38%	61%
Management of key functions	0%	3%	43%	54%
JIT	0%	1%	1%	98%
Autonomation	0%	4%	25%	71%
Standardized work	0%	1%	4%	95%
SPC	0%	1%	5%	94%
Seven Waste	0%	2%	1%	97%
VSM	0%	3%	40%	57%
Error Proofing	0%	2%	31%	67%
Problem solving	0%	1%	23%	76%
Involvement of people	0%	3%	25%	72%
Lean Trainings	0%	2%	8%	90%

(Level 1- Poorly Influencing, Level 5- Highly Influencing)

The percentages of the influencing level 4 & 5 has varied from 54 percent to 98 percent. If we consider all variables from Operations Framework to Lean Training, highest percentage was recorded in Level 4 & 5 for all observed variables.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

Factor analysis was carried out for 17 observed variables to identify factor extraction methods such as Principal Component Factoring (PCF) and Principal Axis Factoring (PAF) and three orthogonal rotations such as Varimax, Equamax and Quartimax.

5.2 Validation of Data for Factor Analysis

Table 5.1: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.867
Bartlett's Test of Sphericity	Approx. Chi-Square	1358.449
	Df	136
	Sig.	.000

Bartlett's Test is used to test the significance of correlation matrix. According to Table 5.1, p-value is significant (0.000). Thus it can be concluded with 95 percent confidence that true correlation matrix of the manifest variables is significantly different from the identity matrix suggesting that correlation structure is suitable for Factor Analysis. Correlation matrix is attached in the Appendix II.

KMO is a measure of sample adequacy. According to Table 5.1, KMO value is 0.867 which is greater than 0.6 hence Factor Analysis is recommended to perform.

5.3 Factor Analysis using PCF and Varimax

Table 5.2: Communalities for Observed Variables

Observed Variables	Initial	Extraction
Ops_Framework	1.000	.909
Policy_Deploy	1.000	.803
Org_Structure	1.000	.845
PMS	1.000	.799
CII	1.000	.645
Ops_skill_dev	1.000	.784
Management_key_functions	1.000	.815
JIT	1.000	.767
Autonomation	1.000	.597
Standardized_work	1.000	.886
SPC	1.000	.887
Seven_waste	1.000	.777
VSM	1.000	.769
Error_Proof	1.000	.701
Problem_Solving	1.000	.729
People_eng	1.000	.517
Lean_Training	1.000	.753

Extraction Method: Principal Component Analysis.

According to Table 5.2, all the final communalities are greater than 0.6 except for People_eng. Communalities of the observed variables varies from 0.517 (People_eng) to 0.909 (Ops_Framework). Therefore, it can be considered that 4-factor model is adequate. The number of factors were decided based on eigen values which are greater than one and the results of the eigen analysis for the correlation matrix of the observed data is shown in Table 5.3 below.

Table 5.3: Total Variance and Eigen values for Observed Variables

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.399	55.290	55.290	9.399	55.290	55.290	4.205	24.738	24.738
2	1.284	7.555	62.845	1.284	7.555	62.845	3.518	20.691	45.429
3	1.200	7.056	69.901	1.200	7.056	69.901	2.675	15.736	61.166
4	1.101	6.479	76.380	1.101	6.479	76.380	2.586	15.214	76.380
5	.782	4.599	80.979						
6	.631	3.712	84.691						
7	.479	2.815	87.506						
8	.408	2.400	89.906						
9	.377	2.216	92.122						
10	.288	1.692	93.814						
11	.239	1.406	95.220						
12	.230	1.351	96.572						
13	.195	1.146	97.717						
14	.149	.879	98.596						
15	.098	.579	99.175						
16	.081	.474	99.649						
17	.060	.351	100.000						

Extraction Method: Principal Component Analysis.

According to Table 5.3, there are four eigen values greater than one. Therefore, it can be concluded that the correlation structure among 17 observed variables can be explained by the four common factors as each observed variable is a linear function of the four factors. Percentage of variance in the system is 76.380.

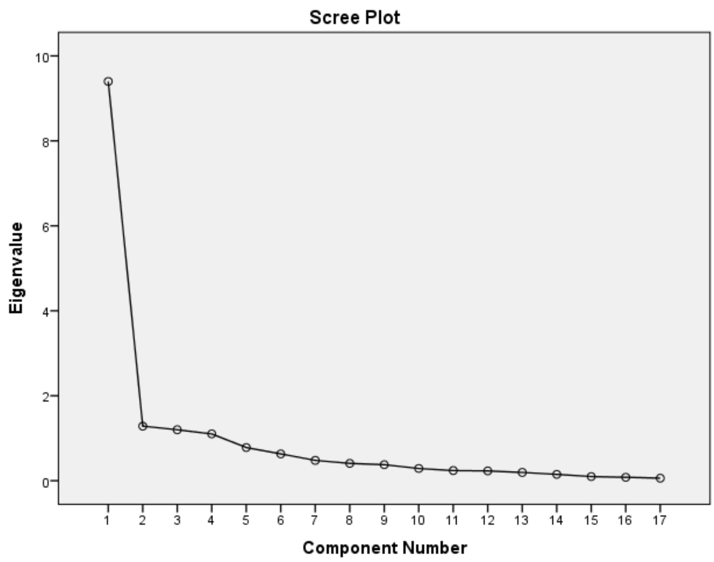


Figure 5.1: Scree Plot of Observed Variables

Figure 5.1, also confirms that there are four major factors inside the system and observed variables were categorized for major four factors according to results in Table 5.4 below.

Table 5.4: Rotated Component Matrix for Four Factors under Varimax

Rotated Component Matrix[a]

Observed Variables	Component			
	1	2	3	4
Ops_Framework	.231	.276	.012	**.883**
Policy_Deploy	.246	.294	.231	**.776**
Org_Structure	**.858**	.130	.200	.230
PMS	**.785**	.247	.225	.266
CII	.412	.217	.401	**.517**
Ops_skill_dev	**.743**	.220	.325	.281
Management_key_functions	**.791**	.362	.058	.236
JIT	.382	**.691**	.197	.323
Autonomation	.355	.357	**.472**	.348
Standardized_work	.221	**.862**	.206	.228
SPC	.129	**.845**	.247	.308
Seven_waste	.529	**.675**	.087	.183
VSM	**.622**	.540	.290	.085
Error_Proof	.401	.299	**.641**	.200
Problem_Solving	.293	.095	**.646**	.466
People_eng	.378	.356	**.491**	-.073
Lean_Training	.025	.118	**.857**	.057

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

According to Table 5.4, eigen values of Organization structure, Performance Management System, Operations skill development, Management of key functions and Value Stream Mapping are greater than 0.5 for Factor 1. Eigen values of Just in Time, Standardized work, Statistical Process control and Seven Waste are greater than 0.5 for Factor 2. Eigen values of Autonomation, Error Proofing, Problem Solving, People Engagement and Lean Training are greater than 0.5 for Factor 3. Eigen values of Operations Framework, Policy Deployment and Continuous Improvement

Infrastructure are greater than 0.5 for Factor 4. The Factor Analysis was performed two times under PCA by changing the rotation method to verify the results.

5.4 Factor Analysis Using PCA and Equamax Rotation

Table 5.5: Rotated Component Matrix for Four Factors under Equamax Rotation

Rotated Component Matrix[a]

Observed Variables	Component			
	1	2	3	4
Ops_Framework	.180	.253	**.901**	.006
Policy_Deploy	.190	.272	**.800**	.228
Org_Structure	**.833**	.143	.280	.231
PMS	**.754**	.256	.317	.253
CII	.364	.205	**.551**	.409
Ops_skill_dev	**.708**	.225	.330	.351
Management_key_functions	**.765**	.374	.287	.089
JIT	.338	**.688**	.366	.215
Autonomation	.308	.347	.385	**.484**
Standardized_work	.176	**.856**	.269	.222
SPC	.079	**.834**	.344	.258
Seven_waste	.495	**.682**	.232	.114
VSM	**.589**	.549	.137	.320
Error_Proof	.356	.293	.241	**.656**
Problem_Solving	.241	.078	.495	**.648**
People_eng	.351	.360	-.034	**.513**
Lean_Training	-.016	.103	.079	**.858**

Extraction Method: Principal Component Analysis.

Rotation Method: Equamax with Kaiser Normalization.

a. Rotation converged in 9 iterations.

The results in Table 5.5 is much similar to the results in table 5.4 even though the orders were slightly different in Factor 3 & 4. Quartimax rotation was also performed and the results were obtained. The results obtained from Equamax is much similar to the results obtained from Varimax method but the results are slightly different with the Quartimax rotation.

5.5 Factor Analysis Using PCF and Quartimax Rotation

Table 5.6: Rotated Component Matrix for Four Factors under Quartimax Rotation

Rotated Component Matrix[a]

Observed Variables	Component			
	1	2	3	4
Ops_Framework	.584	-.109	.077	**.741**
Policy_Deploy	**.649**	.086	.077	.607
Org_Structure	**.832**	-.134	-.364	-.044
PMS	**.857**	-.103	-.230	-.009
CII	**.712**	.195	-.077	.307
Ops_skill_dev	**.853**	.008	-.237	.006
Management_key_functions	**.849**	-.278	-.125	-.034
JIT	**.792**	-.057	.359	.094
Autonomation	**.712**	.259	.074	.134
Standardized_work	**.732**	-.020	.592	.023
SPC	**.696**	.054	.621	.119
Seven_waste	**.808**	-.208	.279	-.060
VSM	**.850**	-.032	.107	-.186
Error_Proof	**.731**	.407	-.004	-.032
Problem_Solving	**.636**	.482	-.129	.275
People_eng	**.604**	.267	.075	-.274
Lean_Training	.400	**.766**	.035	-.073

Extraction Method: Principal Component Analysis.

Rotation Method: Quartimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

According to Table 5.6, eigen values of Policy deployment, Organization structure, PMS, CII, Operations skill development, Management of key functions, JIT, Autonomation, Standardized Work, SPC, Seven Waste, VSM, Error Proof, Problem Solving and People Engagement are greater than 0.5 for Factor 1. Eigen value of Lean Training is greater than 0.5 for Factor 2. There is no factor loading for Factor 3. Eigen values of Operations Framework is greater than 0.5 for Factor 4. The results of the Quartimax rotation is much more different than the results of Varimax and Equamax. Then, the same observed variables were analyzed under Principal Axis Factoring (PAF) for Varimax, Equamax and Quartimax rotations.

5.6 Factor Analysis Using PAF and Varimax Rotation

Table 5.7: Communalities for Observed Variables under PAF

Variables	Initial	Extraction
Ops_Framework	.791	.952
Policy_Deploy	.789	.761
Org_Structure	.805	.810
PMS	.784	.805
CII	.584	.565
Ops_skill_dev	.718	.723
Management_key_functions	.805	.834
JIT	.780	.732
Autonomation	.626	.614
Standardized_work	.841	.900
SPC	.819	.834
Seven_Waste	.747	.690
VSM	.791	.731
Error_Proof	.651	.607
Problem_Solving	.637	.708
People_eng	.506	.438
Lean_Training	.404	.364

Extraction Method: Principal Axis Factoring.

According to Table 5.7, all the initial eigen values and final extraction eigen values are greater than 0.5 except for People engagement & Lean Training. Communalities of the observed variables varies from 0.364 (Lean Training) to 0.952 (Ops_Framework).

Table 5.8: Total Variance and Eigen Values for Observed Variables under PAF

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.181	57.381	57.381	8.927	55.792	55.792	4.034	25.214	25.214
2	1.293	8.080	65.461	1.100	6.876	62.668	3.259	20.369	45.583
3	1.178	7.361	72.822	.856	5.349	68.018	2.222	13.887	59.470
4	1.008	6.300	79.122	.748	4.675	72.692	2.116	13.222	72.692
5	.601	3.757	82.879						
6	.506	3.162	86.041						
7	.413	2.583	88.624						
8	.393	2.454	91.077						
9	.313	1.955	93.033						
10	.262	1.635	94.668						
11	.226	1.415	96.082						
12	.169	1.053	97.136						
13	.160	.998	98.133						
14	.115	.717	98.851						
15	.094	.587	99.437						
16	.090	.563	99.746						
17	.086	.542	100.000						

Extraction Method: Principal Component Analysis.

According to Table 5.8, there are four eigen values greater than one as same as in PCF. Therefore, it is same as the previous result and the conclusion is there would be a 4-factor model. Percentage of variance in the system is 72.692 and it's less than the value obtained from Table 5.3 PCF method.

Table 5.9: Rotated Factor Matrix for Four Factors under PAF and Varimax

Observed Variables	Factor			
	1	2	3	4
Ops_Framework	.300	.272	.070	**.885**
Policy_Deploy	.273	.272	.283	**.730**
Org_Structure	**.824**	.171	.248	.201
PMS	**.784**	.258	.287	.204
CII	.393	.196	.402	**.459**
Ops_skill_dev	**.687**	.224	.332	.300
Management_key_functions	**.798**	.335	.099	.273
JIT	.389	**.677**	.243	.253
Autonomation	.432	.347	**.489**	.262
Standardized_work	.229	**.872**	.240	.174
SPC	.145	**.814**	.283	.265
Seven_Waste	.478	**.636**	.143	.190
VSM	**.610**	.489	.317	.139
Error_Proof	.349	.353	**.591**	.109
Problem_Solving	.339	.128	**.692**	.313
People_eng	.156	.218	**.598**	.091
Lean_Training	.082	.169	**.572**	.026

Extraction Method: Principal Axis Factoring.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Results obtained from PAF Varimax method is similar to the results obtained from PCF Varimax method. The Factor Analysis was performed two times under PAF by changing the rotation method to verify the results. The results were shown in the tables below.

5.7 Factor Analysis Using PAF and Equamax Rotation

Table 5.10: Rotated Component Matrix for Four Factors under PAF and Equamax

Observed Variables	Factor			
	1	2	3	4
Ops_Framework	.218	.246	**.917**	.061
Policy_Deploy	.193	.248	**.766**	.276
Org_Structure	**.789**	.176	.281	.280
PMS	**.744**	.262	.284	.319
CII	.402	.186	**.446**	.412
Ops_skill_dev	**.640**	.222	.371	.356
Management_key_functions	**.760**	.339	.352	.130
JIT	.340	**.672**	.313	.261
Autonomation	.378	.339	.320	**.504**
Standardized_work	.183	**.866**	.227	.254
SPC	.092	**.803**	.310	.290
Seven_Waste	.440	**.636**	.254	.166
VSM	**.570**	.491	.213	.345
Error_Proof	.304	.347	.164	**.606**
Problem_Solving	.277	.114	.361	**.698**
People_eng	.110	.216	.096	**.586**
Lean_Training	.049	.161	.053	**.576**

Extraction Method: Principal Axis Factoring.

Rotation Method: Equamax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

The results of the observed variables under four factors in Table 5.10 is similar to the results in Table 5.5. Therefore, it can be concluded that the selection of four factors in component matrix under PCF and PAF with Equamax rotation are same.

5.8 Factor Analysis Using PAF and Quartimax Rotation

Table 5.11: Rotated Component Matrix for Four Factors under PAF and Quartimax

Observed Variables	Factor			
	1	2	3	4
Ops_Framework	.646	.044	**.716**	-.143
Policy_Deploy	**.665**	.042	.559	.069
Org_Structure	**.841**	-.272	-.088	-.149
PMS	**.868**	-.181	-.086	-.106
CII	**.710**	-.106	.184	.127
Ops_skill_dev	**.831**	-.176	.032	-.028
Management_key_functions	**.858**	-.104	-.016	-.295
JIT	**.769**	.372	.034	-.033
Autonomation	**.754**	.036	.044	.208
Standardized_work	**.716**	.622	-.016	.012
SPC	**.675**	.602	.097	.086
Seven_Waste	**.755**	.309	-.039	-.153
VSM	**.839**	.102	-.125	-.031
Error_Proof	**.691**	.077	-.087	.342
Problem_Solving	**.686**	-.137	.125	.451
People_eng	**.624**	.145	.096	-.254
Lean_Training	.380	.047	-.066	**.461**

Extraction Method: Principal Axis Factoring.

Rotation Method: Quartimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

According to Table 5.11, eigen values of Policy Deploy, Organization structure, PMS, CII, Operations skill development, Management of key functions, JIT, Autonomation, Standardized Work, SPC, Seven Waste, VSM, Error Proof, Problem Solving and People Engagement are greater than 0.5 for Factor 1. No variable is selected to Factor 2. Eigen value of Operations Framework is greater than 0.5 for Factor 3. Eigen values of Lean Training is greater than 0.5 for Factor 4. The results of the Quartimax rotation is much more different than the results of Varimax and Equamax under PAF. Summary of all the analysis methods is mentioned in Table 5.12 below.

5.9 Summary of the Factor Analysis Results

Table 5.12: Summary of all extraction and rotation methods

Extraction Method	Rotation	F1	F2	F3	F4
PCF	Varimax	Org_Structure PMS Ops_skill_dev Management_key_functions VSM	JIT Standardized_work SPC Seven_waste	Autonomation Error_Proof Problem_Solving People_eng Lean_Training	Ops_Framework Policy_Deploy CII
	Equamax	Org_Structure PMS Ops_skill_dev Management_key_functions VSM	JIT Standardized_work SPC Seven_waste	Ops_Framework Policy_Deploy CII	Autonomation Error_Proof Problem_Solving People_eng Lean_Training
	Quartimax	Policy_Deploy Org_Structure PMS CII Ops_skill_dev Management_key_functions JIT Autonomation Standardized_work SPC Seven_waste VSM Error_Proof Problem_Solving People_eng	Lean_Training		Ops_Framework
PAF	Varimax	Org_Structure PMS Ops_skill_dev Management_key_functions VSM	JIT Standardized_work SPC Seven_waste	Autonomation Error_Proof Problem_Solving People_eng Lean_Training	Ops_Framework Policy_Deploy CII
	Equamax	Org_Structure PMS Ops_skill_dev Management_key_functions VSM	JIT Standardized_work SPC Seven_waste	Ops_Framework Policy_Deploy CII	Autonomation Error_Proof Problem_Solving People_eng Lean_Training

	Quartimax	Policy_Deploy Org_Structure PMS CII Ops_skill_dev Management_key_functions JIT Autonomation Standardized_work SPC Seven_waste VSM Error_Proof Problem_Solving People_eng		Ops_Framework	Lean_Training

After going through the results of Table 5.12, it is evident that results for Varimax and Equamax rotation are similar for both extraction methods. Therefore, we can use the Varimax method under PCF to define the Factors since it's the most accurate rotation method and also PCF covers 76 percent of the total variance in the system. According to the Tables 5.4, observed variables can be defined as below.

- Ops_Framework = 0.231 F1+ 0.276 F2+ 0.012 F3+ 0.883 F4+ $\eta_{\text{Ops\_Framework}}$
- Policy_Deploy = 0.246 F1+ 0.294 F2+ 0.231 F3+ 0.776 F4+ $\eta_{\text{Policy\_Deploy}}$
- Org_Structure = 0.858 F1+ 0.130 F2+ 0.200 F3+ 0.230 F4+ $\eta_{\text{Org\_Structure}}$
- PMS = 0.785 F1+ 0.247 F2+ 0.225 F3+ 0.266 F4+ η_{PMS}
- CII = 0.412 F1+ 0.217 F2+ 0.401 F3+ 0.517 F4+ η_{CII}
- Ops_skill_dev = 0.743 F1+ 0.220 F2+ 0.325 F3+ 0.281 F4+ $\eta_{\text{Ops\_skill\_dev}}$
- Management_key_functions = 0.791 F1+ 0.362 F2+ 0.058 F3+ 0.236 F4+ $\eta_{\text{Management\_key\_functions}}$
- JIT = 0.382 F1+ 0.691 F2+ 0.197 F3+ 0.323 F4+ η_{JIT}
- Autonomation = 0.355 F1+ 0.357 F2+ 0.472 F3+ 0.348 F4+ $\eta_{\text{Autonomation}}$
- Standardized_Work = 0.221 F1+ 0.862 F2+ 0.206 F3+ 0.228 F4+ $\eta_{\text{Standardized\_Work}}$
- SPC = 0.129 F1+ 0.845 F2+ 0.247 F3+ 0.308 F4+ η_{SPC}
- Seven_Wastes = 0.529 F1+ 0.675 F2+ 0.087 F3+ 0.183 F4+ $\eta_{\text{Seven\_Wastes}}$
- VSM = 0.622 F1+ 0.540 F2+ 0.290 F3+ 0.085 F4+ η_{VSM}

- Error_Proof = 0.401 F1+ 0.299 F2+ 0.641 F3+ 0.200 F4+ η_{Error_Proof}
- Problem_Solving = 0.293 F1+ 0.095 F2+ 0.646 F3+ 0.466 F4+ $\eta_{Problem\_Solving}$
- People_Eng = 0.378 F1+ 0.356 F2+ 0.491 F3- 0.073 F4+ η_{People_Eng}
- Lean_Training = 0.025 F1+ 0.118 F2+ 0.857 F3- 0.057 F4+ $\eta_{Lean\_Training}$

Where η is a constant.

Factor score coefficients obtained from PCA and Varimax is shown in Table 5.13 below.

Table 5.13: Factor Score Coefficients form PCA and Varimax

Component Score Coefficient Matrix

Observed Variables	Component			
	1	2	3	4
Ops_Framework	-.098	-.057	-.188	**.567**
Policy_Deploy	-.115	-.056	-.031	**.451**
Org_Structure	**.377**	-.193	-.068	-.036
PMS	**.297**	-.112	-.058	-.022
CII	.015	-.115	.097	**.218**
Ops_skill_dev	**.259**	-.135	.018	-.012
Management_key_functions	**.308**	-.013	-.182	-.047
JIT	-.043	**.259**	-.070	.009
Autonomation	-.033	.012	**.160**	.063
Standardized_work	-.159	**.423**	-.044	-.067
SPC	-.229	**.413**	-.008	.007
Seven_waste	.090	**.256**	-.149	-.105
VSM	**.156**	.141	.001	-.196
Error_Proof	.004	-.028	**.292**	-.068
Problem_Solving	-.058	-.186	**.305**	.192
People_eng	.055	.087	**.225**	-.261
Lean_Training	-.179	-.053	**.547**	-.100

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

According to table 5.13 Factors can be defined as below. (Z is the standardized value of the variables)

$$F1 = 0.377\ Z_{OrgStructure} + 0.308\ Z_{Management\_key\_functions} + 0.297\ Z_{PMS} + 0.259\ Z_{Ops\_skill\_dev} + 0.156\ Z_{VSM} \quad (4.1)$$

$$F2 = 0.423\ Z_{Standardized\_work} + 0.413\ Z_{SPC} + 0.259\ Z_{JIT} + 0.256\ Z_{Seven\_Waste} \quad (4.2)$$

$$F3 = 0.547\ Z_{Lean\_Training} + 0.305\ Z_{Problem\_Solving} + 0.292\ Z_{Error\_Proof} + 0.225\ Z_{People\_Eng} + 0.160\ Z_{Autonomation} \quad (4.3)$$

$$F4 = 0.567\ Z_{Ops\_Framework} + 0.451\ Z_{Policy\_Deploy} + 0.218\ Z_{CII} \quad (4.4)$$

Formula 4.1 indicates that Organization Structure, Management of key Functions, Performance Management System, Operations Skill Development, and VSM belongs to Factor 1. These variables represent how the organization operates. A proper structure which defines organization roles and responsibilities, major operation functions and supporting functions, performance management system to measure the performance of the operation and employees, trainings to develop the skill and process maps and VSM to standardize the operation and identify waste and reduce lead time in the operation.

Formula 4.2 indicates that Standardized Work, Statistical Process Control, Just in Time and Seven Wastes belongs to Factor 2. These variables defines how to eliminate waste. A standard operations procedures, control limits to check the capability of the operation, produce only when it’s required and identify and eliminate seven types of waste to improve operation excellence.

Formula 4.3 indicates that Lean Training, Problem Solving, Error Proof, People Engagement and Autonomation belongs to Factor 3. These variables defines improvements of people, processes in the organization. People in all levels in the organization need to be given trainings on Lean on time to time. A structural way to solve problems, identify the root cause, controls to minimize errors, engagement in people to generate new ideas and automate the processes with human thinking to improve processes.

Formula 4.4 indicates that Operations Framework, Policy Deployment and Continuous Improvement Infrastructure belonged to Factor 4. This defines the culture of the organization, the way of organization mission, vision aligns to organizations goals and KPIs and mechanism of improving those continuously.

5.10 Summary of Chapter 5

Correlation matrix and Bartlett's test were also significant and the KMO value was highly recommended to conduct the Factor Analysis. Factor Analysis was performed under PCF and Varimax method first and Equamax, Quartimax rotations were also performed under PCF to confirm the results. Factor Analysis was done under PAF with the same rotation methods to identify major factors. It was observed that there were four major factors which extracted 76 percent of the total variance of the system. Four factors were defined using Factor Score Coefficients and the results were interpreted using Formula 4.1 to 4.4

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The objective of this study was to identify the factors influence on the Lean practices and sustainability in the Sri Lankan context. There were four major factors identified from the Factor Analysis on practicing and sustaining Lean. Factor one consists of Organization Structure, Performance Management System, Management of key Functions, Operational Skill Development and VSM. These variables mainly cover Management Infrastructure. Factor two consists of Standardized Work, Statistical Process Control, Just in Time and Seven Wastes. These variables mainly emphasize Waste Elimination. Factor three consists of Lean Trainings, People Engagement, Problem Solving, Error Proofing and Autonomation. There variables cover Process Improvement through Knowledge Enhancement. Factor four consists of Operations Framework, Policy Deployment and Continuous Improvement Infrastructure. These variables mainly emphasize Organization Culture. Therefore, we can conclude that there are four major factors influence on Lean practice and sustainability. Those can be defined as Management Infrastructure, Waste Elimination, Process Improvement through Knowledge Enhancement and Organization Culture. Organizations can use these models defined in formula 4.1, 4.2, 4.3 and 4.4 to increase their productivity and performance by focusing on each factors.

6.2 Recommendations

Through identification of the major four factors which influence on Lean practices and sustainability, companies can focus on these factors to achieve operations excellence. They can achieve high throughput, variety of products and high profits by focusing on these four major factors. However, Muri (overburdening people or machines), Mura (unevenness) and Heijunka (Production levelling) were not considered in this study because of the time and cost factors. Therefore, if this research is used for future analysis, I would like to recommend them to increase the sample size and do an observational study since the responses receive through questionnaires are not reliable sometimes. Also level of the people who fills the questionnaires also need to be considered since people from higher management levels might be having better opinions and lower level must be having better opinions on overburdening & unevenness of work. If this research performs again, results might get varied due to organization structural changes, management changes, economic & political crisis.

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Appendix I: Questionnaire

Factors influence on Lean Practices in Apparel Industry- Sri Lanka

This questionnaire is aimed to gather information to identify the factors influence on Lean Practices in Apparel industry Sri Lanka. This research is being done in partial fulfillment of the award of Master of Business Statistics (MBS).Your objective answers for this questioner will contribute to the success of this research. As this research is being conducted for academic purpose, information you give will be treated confidential.

*Required

Company Name: ____________________

1 Is your company Practicing Lean?

◯ Yes

◯ No

2 Please rate the current practicing level according to your point of view.

	1	2	3	4	5	
Poorly Practicing	◯	◯	◯	◯	◯	Highly Practicing

3. Please rate your opinion on how the Operations Framework influence on practicing and sustaining Lean Management

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

4. Please rate your opinion on how the Policy Deployment methods and targets to monitor Key Performance Indicators (KPI) influence on practicing and sustaining Lean Management

	1	2	3	4	5	
Poorly Influencing	○	○	○	○	○	Highly Influencing

5. Please rate your opinion on how the organization structure influence on practicing and sustaining Lean Management

	1	2	3	4	5	
Poorly Influencing	○	○	○	○	○	Highly Influencing

6. Please rate your opinion on how the Performance Management System influence on practicing and sustaining Lean Management

	1	2	3	4	5	
Poorly Influencing	○	○	○	○	○	Highly Influencing

7. Please rate your opinion on how the continuous improvement infrastructure influence on practicing and sustaining Lean Management

	1	2	3	4	5	
Poorly Influencing	○	○	○	○	○	Highly Influencing

8. Please rate your opinion on how the process of developing operations skills influence on practicing and sustaining Lean Management

	1	2	3	4	5	
Poorly Influencing	○	○	○	○	○	Highly Influencing

9. Please rate your opinion on how the management of key functional processes influence on practicing and sustaining Lean.

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

10. Please rate how the Just In Time techniques such as QCO, Preventive Maintenance, Cycle time reduction influence on practicing and sustaining Lean.

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

11. Please rate your opinion on how the Autonomation influence on practicing and sustaining Lean.

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

12. Please rate how the Standardized work influence on practicing and sustaining Lean.

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

13. Please rate your opinion on how the Six-Sigma and Statistical Process Control techniques influence on practicing and sustaining Lean

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

14. Please rate your opinion on how the diagnosis of Seven Wastes influence on practicing and sustaining Lean.

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

15. Please rate how the Value Stream Mapping (VSM) influence on Lean Management to streamline the process and eliminate wastes

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

16. Please rate how the Poka Yoke/ Error Proofing methods influence on Lean to minimize losses

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

17. Please rate how the Problem Solving techniques influence on Lean to identify the root causes and minimize losses

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

18. Please rate your opinion on how the involvement of people to generate new ideas/ improvements influence on practicing and sustaining Lean.

	1	2	3	4	5	
Poorly Influencing	◯	◯	◯	◯	◯	Highly Influencing

19. Please rate your opinion on how Lean Management Trainings for the employees at all levels influence on practicing and sustaining Lean

	1	2	3	4	5	
Poorly Influencing	○	○	○	○	○	Highly Influencing

20. Do you think an effective Lean Management system would increase the Productivity/ Performance of the organization/ teams/ individuals?

○ Yes

○ No

21. If yes, please select a range which you think the productivity level would increase.

○ 0%-20%

○ 21%-40%

○ 41%-60%

○ 61%-80%

○ 81%-100%

22. Open ended Comments if any

………………………………………………………………………………………

Submit

Since this questionnaire is a Google form, it is online available at: https://goo.gl/forms/kZxdYz1KhMC5R3X72

Appendix II: Correlation Matrix

Correlation Matrix

		Ops_Framework	Policy_Deploy	Org_Structure	PMS	CII	Ops_skill_dev	Management_key_functions	JIT	Autonomation	Standardized_work	SPC	Seven_Waste	VSM	Error_Proof	Problem_Solving	People_eng	Lean_Training
Correlation	Ops_Framework	1.000	.830	.513	.507	.541	.542	.596	.550	.500	.494	.522	.459	.447	.338	.465	.352	.137
	Policy_Deploy	.830	1.000	.446	.497	.590	.571	.535	.541	.519	.470	.509	.520	.531	.484	.542	.455	.236
	Org_Structure	.513	.446	1.000	.826	.610	.739	.802	.592	.564	.435	.389	.537	.674	.499	.541	.458	.269
	PMS	.507	.497	.826	1.000	.638	.740	.784	.616	.665	.515	.473	.578	.708	.557	.538	.441	.259
	CII	.541	.590	.610	.638	1.000	.635	.545	.524	.564	.443	.478	.462	.528	.458	.604	.361	.300
	Ops_skill_dev	.542	.571	.739	.740	.635	1.000	.768	.547	.620	.483	.464	.595	.669	.516	.569	.492	.332
	Management_key_functions	.596	.535	.802	.784	.545	.768	1.000	.625	.566	.566	.471	.663	.725	.475	.464	.478	.224
	JIT	.550	.541	.592	.616	.524	.547	.625	1.000	.581	.769	.760	.717	.611	.591	.424	.462	.313
	Autonomation	.500	.519	.564	.665	.564	.620	.566	.581	1.000	.573	.566	.529	.635	.568	.638	.381	.363
	Standardized_work	.494	.470	.435	.515	.443	.483	.566	.769	.573	1.000	.877	.720	.658	.512	.399	.391	.354
	SPC	.522	.509	.389	.473	.478	.464	.471	.760	.566	.877	1.000	.658	.597	.488	.431	.445	.328
	Seven_Waste	.459	.520	.537	.578	.462	.595	.663	.717	.529	.720	.658	1.000	.750	.514	.460	.520	.149
	VSM	.447	.531	.674	.708	.528	.669	.725	.611	.635	.658	.597	.750	1.000	.674	.532	.596	.262
	Error_Proof	.338	.484	.499	.557	.458	.516	.475	.591	.568	.512	.488	.514	.674	1.000	.608	.502	.455
	Problem_Solving	.465	.542	.541	.538	.604	.569	.464	.424	.638	.399	.431	.460	.532	.608	1.000	.314	.446
	People_eng	.352	.455	.458	.441	.361	.492	.478	.462	.381	.391	.445	.520	.596	.502	.314	1.000	.383
	Lean_Training	.137	.236	.269	.259	.300	.332	.224	.313	.363	.354	.328	.149	.262	.455	.446	.383	1.000
Sig. (1-tailed)	Ops_Framework		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.073
	Policy_Deploy	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.006
	Org_Structure	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002
	PMS	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003
	CII	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
	Ops_skill_dev	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Management_key_functions	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.008
	JIT	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000
	Autonomation	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	Standardized_work	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000
	SPC	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000
	Seven_Waste	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.056
	VSM	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.002
	Error_Proof	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000
	Problem_Solving	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	People_eng	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	Lean_Training	.073	.006	.002	.003	.001	.000	.008	.000	.000	.000	.000	.056	.002	.000	.000	.000	