



Faculty of Engineering and the Built Environment

Department of Industrial Engineering

**Comparative analysis of the implementation of Toyota Production
System between a tier-one and tier-two supplier**

Prenisha Govender

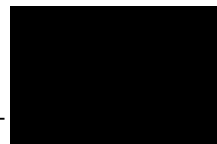
(Student Number - 21509155)

**Submitted in fulfilment of the requirements
for the Master of Engineering degree**

February 2024

Supervisor: Dr M Dewa

Signature: _



Declaration

I hereby declare that this submission is my own and to the best of my knowledge. This dissertation neither contains material previously published nor written by another person, nor material that to a major extent has been accepted for the award of any other degree at Durban University of Technology or any other educational institution. I also declare that the intellectual content of this thesis is a product of my work. Any contribution made to the research by others especially in the use of equipment for sample analysis has been explicitly acknowledged in the dissertation.



Prenisha Govender 21509155

Date: 13/02/2024

Dedication

I dedicate this dissertation to my parents, sister and my close friends. Thank you for pushing me to discover my greater potential. I want you all to know that you can achieve anything you set your mind to. Without your support, this would have not been possible. Thank you for giving me strength when I thought this would have not been possible. This was by far the hardest struggle, but here I am.

I would also like to dedicate this thesis to all women in engineering. Life is tough but so are you. You can do it. All you need to do is begin.

Mom and dad, I hope this achievement has fulfilled the dream you had envisioned for me. Be prepared, there's more on its way.

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- My family, my father, Mr Ronnie Govender; Mother, Sandra Govender and sister, Kassandria Govender who has always been supportive towards my education. Your encouragement and ongoing support have led me to this moment.
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Abstract

The Toyota Production systems (TPS) is a methodology that is widely used in the manufacturing automotive industry. The Toyota pyramid model consists of four levels which can be dissected into the first level of philosophy, the second level named process, the third pillar of people and partners, and lastly the problem-solving level. These are also characterised by 14 principles of the model. However, many suppliers face challenges in implementing these principles from the Toyota pyramid model due to lack of knowledge, understanding or available framework for easy implementation and guidance. This study aims to conduct a comparative analysis of the level of implementation of the 14 principles of the Toyota pyramid model by a tier-one and tier-two supplier. This study also identified areas of strengths and weakness and made provisions for continuous improvement initiatives at each supplier for future work.

A quantitative research methodology with a questionnaire as the research instrument, was adopted for this study. A 5-point Likert type scale was used to elicit responses from 25 research participants from the tier-one and tier-two suppliers. Data analysis was conducted through descriptive values of the means, skewness and kurtosis, and an independent sample t-test was used as an inferential tool to establish the relationship between the tier-one and tier-two supplier. Value stream mapping was also deployed to identify the current production processes and kaizen bursts that characterized the two organisations.

The results from the comparative analysis of the level of implementation of the Toyota pyramid model revealed that tier-one supplier was demonstrating better performance than tier-two supplier in the implementation of the 14 principles. In addition, the results demonstrated that principle 1, from the philosophy level had a higher mean or was stronger for each supplier. On the hand, principle 8 and principle 12 were found to be weaker in each supplier respectively.

The areas of improvement which were highlighted in the kaizen bursts on the value stream map were addressed and kaizen implementation was undertaken. These improvement initiatives included rebalancing a seat-cover assembly line and deployment of an andon management system at the tier-one supplier to improve line efficiency and line management. A framework was also proposed for the tier-two supplier to bridge the gap in its practice for implementation of the Toyota pyramid

model principles. Additional principles were added to this framework to ensure an easier and understandable methodology and framework to be referred to for suppliers and companies to improve.

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Publications

1. Govender, P. and Dewa, M., 2022. Use of kaizen principle and line balancing technique for process improvement in the assembly of automotive components. *South African Journal of Industrial Engineering*, 33(3), pp.69-82.
2. Govender, P and Dewa, M. 2023. The implementation of an andon production management system to improve the efficiency of tracking of output scores, Proceedings of International Conference on Industrial Engineering, Systems Engineering and Engineering Management, 2 – 4 October 2023, Somerset West, South Africa, p 1785 -1798.
3. Govender, P. and Dewa, M. 2023. The Implementation of Six Sigma and DMAIC Methodology to Increase Productivity and Meet Customer Requirements. Proceedings of the International Conference on Industrial Engineering and Operations Management, Lusaka, Zambia, April 4-6, 2023, IEOM Society International.

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List of Acronyms

LM	Lean Manufacturing
SME	Small and Medium Enterprises
TPS	Toyota Production System
TBSA	Toyota Boshoku South Africa
TSAM	Toyota South African Motors
VSM	Value Stream Mapping

Glossary of Terms

Lean Manufacturing	A production system aimed at reducing wastes within production processes.
Just-in-time	A strategy to organize raw materials directly from suppliers to customers on a predetermined schedule.
Jidoka	A system where a process or machine automatically stops in detection of an abnormal condition e.g. a defect.
Kaizen	A Japanese concept referring to continuously improving business operations.
Kanban	A Japanese term that means billboard or sign board, a tool used to visualize work and optimize the flow of work among the team.
Lead time	Lead time can be described as the amount of time that passes from the start of a process until it is complete.
Toyota Production System	TPS is an integrated socio-technical system developed by Toyota that comprises its practices and cultures. Categories such as Jidoka, the pull system are part of the 14 principles.
Muda	Muda is a core concept of waste in TPS. Muda means wastefulness, uselessness and is applied to processes which has a lot of waiting time and stoppages.
Six Sigma	Techniques used to improve business processes by greatly using the DMAIC methodology. The DMAIC Methodology stands for Define, Measure, Analyze, Improve and lastly Control.

Tier-one supplier	A tier-one supplier can be described as when a manufacturer of products is almost close to the end product. This supplier provides the OEM in making the final product.
Tier-two supplier	A supplier who is vital to the supply chain and are usually limited in what they can produce. These are the smaller companies or sub-contractor to the tier-one supplier.
Takt time	Takt time can be described is the time needed to complete to meet customer expectations. This is calculated using the demand value from the customer as well as the available time in a shift.
Work-in-process	Work in process can be described as the minimum amount of inventory on the line that will allow the operator to flow product efficiently.
Production Capacity Sheet	This is used to calculate the capacity of each machine in a set of process to confirm the true capacity and to identify and eliminate bottlenecks.

CHAPTER 1 : INTRODUCTION

1.1 Introduction

Lean manufacturing and Toyota production systems (TPS) are seen as the continuous improvement benchmark methodologies for the manufacturing industry today. Their primary goal is to enhance customer satisfaction, minimise operational costs and to remain competitive in the world market (Liker, 2004). The success of any lean implementation, TPS or six sigma principle is in creating an atmosphere of continuous learning and an environment that not only accepts but embraces change.

The implementation of lean manufacturing also known as TPS has huge benefits such as quality improvement, cycle time reduction and customer responsiveness. Toyota Boshoku South Africa (TBSA) is a sister company of Toyota South Africa where the Toyota Production Systems has been instilled within the work environment and continuous improvement is part of daily duties. TBSA is a Japanese cultured company also considered as a tier-one supplier as it is a direct supplier to the main plant Toyota South Africa Motors (TSAM). According to Parkes (2015), lean manufacturing was developed in Japan, in the Toyota's plant and then copied by organisations throughout the world. The concept of "Lean management" is seen as slimming the organisation, slimming it of all "unhealthy weight" or waste that is inherent in the production of goods and services.

Rose *et al.* (2017) explains that all small and medium enterprises (SMEs) have the following goals in mind i.e., to be ranked number one in the SME industry, to strive towards world-class performance, to be responsive and flexible strategically and compete in the competitive global market place. Continuous process improvements are needed for companies to keep up with the dynamic environment and to compete in the automotive industry. SMEs play a vital role in the supply chain and economy of a country and are continuously under pressure to survive in the market. As mentioned by Shrimali, (2019), small and medium size enterprises are a critical component in any supply chain. These companies employ a large percentage of the population and contribute a great value to the economy. TPS or lean manufacturing methodologies implementations often fail when

being implemented in these industries. In this research, the implementation of TPS at an SME, a tier-two supplier will be analysed and compared with a tier-one supplier, these companies are both based in Durban, South Africa.

1.2 Research Problem

The current problem within SMEs is that these companies are failing in the global market and according to Hu *et al.* (2015), this is due to the challenges faced during the implementation of lean principles or lack of knowledge. Rose *et al.* (2017) mentions that although suppliers aim to implement TPS, they lack the knowledge to fully adopt the principles correctly, to standardise work and sustain that principle for more than six months. At the tier-two SME supplier, the problem at hand is that there is not much knowledge of TPS that is being shared and any improvement activities are not sustained and the operators often revert back to the previous inefficient methods. There is also no available framework to assist in the easy implementation of these improvement methodologies of TPS. In some cases, there is also much muda in their processes and no continuous improvement initiatives to improve or eliminate such waste. There are also many continuous improvement issues at the tier one supplier where there are also aspects of their production process that can be improved on and gaps in their use of the TPS methodology. In addition, there are also many challenges when it comes to the subsidiaries of the TPS structure such as JIT and the muda amongst others in respect of the tier-one supplier. It was also observed that the cover assembly sewing line for the tier-one supplier faced many bottlenecks as well as difficulty in tracking their output scores.

1.3 Aim of study

The aim of the study is to conduct a comparative analysis of a tier-one and tier-two supplier on their knowledge and implementation of the 14 principles of the Toyota model. This study aims to uncover the knowledge levels of the two organisations in the implementation of the 14 principles of the Toyota model. This research also proposes improvement strategies that would benefit each supplier and a framework was also

developed, not to assist the tier-two supplier only, but also to assist any other suppliers in the case of implementing the principles of the Toyota model.

1.4 Research Objectives

The research objectives are as follows:

- To identify the current production processes that characterize a tier-one and tier-two supplier.
- To identify the current principle status of the Toyota Production System used by a tier-one and tier-two supplier.
- To investigate which of the 14 principles of the TPS methodology are either stronger or weaker in the tier-one and tier-two supplier.
- To implement continuous improvement initiatives for tier 1 supplier.
- To develop a framework for optimal Toyota Production System implementation by the tier 2 supplier.

1.5 Research Methodology

A Gemba walk was carried out to identify the current production processes that characterised a tier-one and a tier-two supplier. A quantitative study was carried out on the key elements of the Toyota Production System using a questionnaire to establish the strengths and weaknesses of the key pillars by a tier-one and tier-two supplier. A framework was then developed for the implementation of the principles of the Toyota-way model in conjunction with the comparative analysis. Additional principles were added to ensure easier and stable implementation by any supplier or organisation in the future.

1.6 Significance of the study

This research intends to make an original contribution to the body of knowledge and understanding as to how lean manufacturing and principles of the Toyota Production Systems is implemented. Improvement initiatives extracted and linked to the Toyota principles were implemented as well a framework for a successful implementation for

future activities. Publication of articles has also added to the body of knowledge on line balancing, kaizen implementation, lean as well as andon management systems.

1.7 Limitations and delimitations of study

The limitations and delimitations of the study is briefly explained below:

1.7.1 Limitations

It was found that it was easier to implement process improvements at the tier-one supplier as compared to the tier-two supplier due to the tier-one supplier having a much more knowledgeable understanding of the 14 principles of the Toyota model as compared to the tier-two supplier. This was also due to the fact that the tier-two supplier was a developing organisation while the tier-one supplier is an established organisation.

1.7.2 Delimitations

In order to narrow down the study and make it more manageable and relevant to the research goal, this dissertation focused or investigated the implementation of 14 principles of the Toyota model by tier-one supplier and tier-two supplier. Participants with experience less than two years were excluded from the study as experience in the implementation and knowledge of the TPS principles were required in order to have relevant data captured.

1.8 Dissertation format

This chapter will provide an overview of the format of this dissertation. The dissertation is categorized in 6 chapters which is explained briefly below.

Chapter 1: Introduction

This chapter will provide an overview of the dissertation. The aim of the study and research objectives of this dissertation are stated. The research method will be briefly discussed as well as the significance of this study.

Chapter 2: Literature review

Literature review consists of articles in which the above topic is supported and motivated. The literature provided insight on different organisations and their cultures as well as

analysis of the TPS House. The 14 principles of the Toyota way model were also emphasised with each principle being explained.

Chapter 3: Case study background

This chapter presents the company's being studied, i.e. the tier-one and tier-two supplier that was non-randomly selected. Here, a value stream map of each supplier and their processes are described and mapped out with cycle times as well as kaizen bursts at each supplier being highlighted.

Chapter 4: Research methodology

This chapter focuses on the methodology for the study, a quantitative research approach was used and a structured questionnaire was used as the research instrument. Ethical considerations were also part of this study and necessary criteria for the study were explained.

Chapter 5: Results and discussion

The results from the data that was collected were displayed graphically and systematically to give an overview of the responses given. Data analysis was conducted through descriptive values of the means, skewness and kurtosis, and an independent sample t-test was used as an inferential tool to establish the relationship between the tier-one and tier-two supplier. The areas of improvement were highlighted and kaizen implementation was undertaken. A framework was also proposed for the tier-two supplier to bridge the gap in its practice for implementation of the Toyota pyramid model principles.

Chapter 6: Recommendations and conclusions

Recommendations and improvement strategies were drawn and proposed for the individual organisations. Future work for study is also discussed in this chapter.

1.9 Conclusion

Continuous improvements are mandatory for manufacturing processes to evolve, meet customer requirements, eliminate muda and meet productivity requirements. This chapter has outlined the background to the study as well the main objectives that the dissertation will follow. Research objectives were also outlined as investigating each supplier via a value stream map and exploring which principles of the Toyota model were either stronger or weaker. The structure of this research was also outlined and the research methodology that was adopted is explained further in Chapter 3. The following chapter reviews literature relating to TPS, the benefits of the methodology, the 14 pillars explained as well as to why TPS is benchmarked in the manufacturing industry.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the literature supporting the aim of the study, which is to compare the implementation of TPS between a tier-one and a tier-two supplier. Randolph (2009) stated that literature review is a means of demonstrating an author's knowledge about a particular field of study. It also plays a role in synthesising and gaining a new perspective and identifying recommendations for future research. This chapter commences with history of TPS and why it is benchmarked especially in the manufacturing environment: it then goes on to explain the 14 principles and the TPS house, the success factors as well as downfalls of the implementation of this methodology.

2.2 Brief history of Toyota Production Systems

According to Dekier (2012), the TPS can date back to the twentieth century and the father of the system was Sakichi Toyoda, a manufacturing engineer. Sakichi Toyoda first invented a motor driven loom which he incorporated a specialised mechanism that stopped in the case of the thread breaking off. This mechanism later became one of the pillars of the TPS house, known as Jidoka (automatisation with human manufacturing). This is where TPS first originated and Toyota was then forced to change its methods of production due to diverse automobiles in smaller quantities being required. This had to be done in order to compete with the mass production that characterised the automotive industry. Lean in any manufacturing environment also refers to the Toyota Production system established by the well-known Toyota Corporation (Towill, 2010). Increased capacity, cycle time reduction and improved customer satisfaction are just some of the benefits of introducing lean at an organisation (Shrilai, 2017).

2.3 TPS methodology explained

TPS is still regarded as the most popular production concept and this ground-breaking concept and approach to implement a lean production manufacturing process on the shop floor, has revolutionised in the manufacturing environment.

The seven wastes listed above is summarised and explained further in Table 2.1 below:

Table 2.1 : The seven wastes explained

Waste	Waste defined	Potential causes
Overproduction	Producing more than what is needed, faster than needed or before.	Poor planning, lack of communication, lengthy set up times. Producing more than required. Possible damage of products kept.
Waiting	Idle time that occurs when co-dependent events are not fully synchronised.	Inconsistent work methods, production bottlenecks, lack of proper materials and equipment.
Transportation	Any material improvement that does not directly support immediate production.	Improper facility layout, poor production planning, poor work place organisation.
Over-processing	Redundant effort which adds no value to a product or service.	Decision making at appropriate levels, ineffective policies and procedures at manufacturing process.
Inventory	Any supply in excess of process requirements necessary to produce goods and services in a Just-in-time manner.	Stock manufactured and kept in warehouse. Items not needed being produced.
Motion	Any movement of people which does not contribute added value to the product or service.	Process material not within reach at process. Material needed to manufacture a distance away.
Defects	Repair or rework of a product or a service to fulfil customer requirements	Process causing defects, which is money waste.

Source: (Hines, 1997)

methodology. This article also emphasised that the main objective of lean manufacturing is to eliminate everything that does not add value to the customer.

The Toyota Way	Continuous improvement	Challenge	1. Long-term philosophy
		<i>Kaizen</i>	2. Create flow
			3. Use a pull system
			4. Level out the workload
			5. Stop and fix the problem
			6. Standardise tasks
			7. Use visual control
			8. Use reliable, tested technology
			14. Continual organisational learning through <i>kaizen</i>
	Respect for people	<i>Genchi genbutsu</i>	12. Go and see for yourself to understand the situation
			13. Make decisions slowly by consensus
		Respect	9. Grow leaders who live the philosophy
			11. Respect, challenge, and help your suppliers
		Teamwork	10. Respect, develop, and challenge your people and teams

Figure 2.2 : The 14 Principles divided into the two categories

Source: (Dyk et al., 2016)

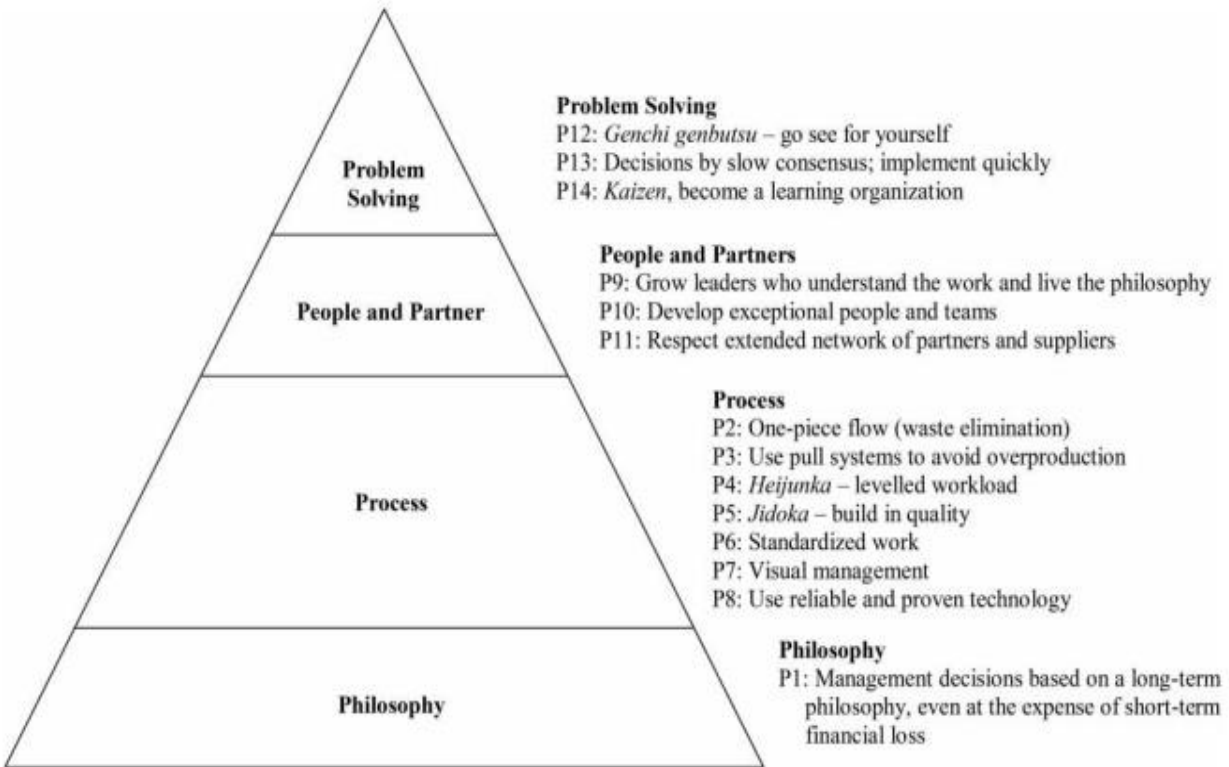


Figure 2.3 : The Toyota way model: Gao and Low (2014)

Figure 2.3 shows the TPS model used in the relation to the questionnaire developed. This questionnaire was used to achieved the objective of determining the current principle status of the Toyota Production System used by a tier-one and tier-two supplier as well as the third objective of investigating which principles are either stronger or weaker in the tier-one and tier-two supplier. Each of the 14 Principles of the TPS model are further individually explained below.

Principle 1: Management decisions based on a long-term philosophy, even at the expense of the short-term financial loss

According to Gao and Low (2014), the Toyota philosophy is to encourage management to base their decisions on a long-term vision. Gao and Low (2014) further identify four sub-elements which are constant purpose, customer focus, self-reliance and responsibility. Aspects such as defining value from the view point of customer, developing a long-term vision are items pertaining to establishing a long-term philosophy. According to Liker (2011), the most important factors for success are patience, a focus on long-term rather than short-term results, reinvestment in people, product, and plant, and an

unforgiving commitment to quality. With the Toyota philosophy, it is safety first, quality second, third volume and lastly profit making. However, management should re-prioritize these as the time changes for which is best for the company and the longevity of it (Liker, 2011).

Principle 2: One-piece flow (waste elimination)

As defined by Ani (2012), one-piece flow can be described as a mean of parts are moved through operations from one point to another with no work in progress in between. For example, in a one-piece flow pull production system, the producer begins production based on a signal, Kanban or e-Kanban notification. It can also be described as a sequence of product or of transactional activities in a cellular environment. That product is then made in time, one at a time (Sundae *et al.*, 2014). As compared to batch production, where a large number of products are sent together as a group through each operational step, one-piece flow focuses on one product or process at a time with minimal changeover times (Marton and Paulova, 2013). The very basic concept of reduction of waste was described by Shingo, through one-piece flow in processes, companies are able to eliminate waste which can enable them to produce efficiently and gain a competitive advantage in the industry (Thun *et al.*, 2011).

Principle 3: Use pull system to avoid overproduction

A pull system enables the production of a company or process based on the requirements of the customer only. It can be simply described as the customer “pulls” the required specification of product from the producer (Sundar *et al.*, 2014). The product is manufactured according to customer requests via a production control system. In an article by Araujo *et al.* (2021), pull production is one of the most important pillars of TPS whereby the upstream process only produces when the downstream process requires an item. Production of a product is only triggered after taking into account the customer demand and the signal from the downstream to the upstream process. By using the pull system, this is a method to controlling the workload in the system. This also assists in ensuring that there is a balance between demand and production and to establish a synchronized production system (Tekin *et al.* 2019).

Principle 4: Heijunka – levelled workload

Heijunka is one of the lean manufacturing tools and is explained as a concept whereby a sequence or elements of a job is organised. The benefits of heijunka are reduced overtime on processes, amending processes to meet challenging demands in production and reduced factory area (Guner, 2014). In an article by Chabowski *et al.* (2016), heijunka or leveling production is relatively aimed at eliminating jumps in production. Leveling of production was further explained as a method of sequencing products in order to balance the production process, increase productivity and flexibility by eliminating waste and minimising differences in load workstations. Rewer *et al.* (2016) mentions that by using heijunka in your production process, focus is placed on the determination of the sequence and the amount of flow from the process so that the current demand is realised from the warehouse instead of sudden changes in the production schedule.

Principle 5: Jidoka – build in quality

Tekin *et al.* (2018) describes Jidoka as a system that enables the machine or operators to automatically detect a defect or any abnormal situation and then stop production. By using Jidoka, efficiency of the equipment is increased since equipment has the ability to detect emerging abnormalities and immediately stop the operation which allows for a more effective process (Trojanowska *et al.*, 2016). Workers can also frequently monitor different stations simultaneously thereby reduce labour costs. It is JIT and Jidoka that have the strongest significance on operational performance and productivity (Lawal and Elegunde, 2020).

Principle 6: Standardised work

Standardised work is considered a basic tool for continuous improvement and can be described as a method for efficient production where a production process is set on a defined sequence (Govender and Dewa, 2023). Standardised work contains process steps of an operator, work sequences, cycle time, work in process and process control (Balaji *et al.*, 2014). This also confirmed by Mariz *et al.* (2012) who stated that the requirements to establish standardised work consists of elements such as takt time, sequence and work-in-process. Mariz *et al.* (2012) further argues that there is also documentation that coincides with standardised work, which is production capacity sheet,

standardised work combination table and chart. However, there are other tools that can be used to ensure standardised work can be implemented such as operator balance chart, job instruction, verification process check sheet, and visual controls. Standardised work is a tool in lean manufacturing as this improves the stability of production processes. In an organized way standardised work allows processes to be done in the same way, in the same manner, order and time at an improved cost (Rewers *et al.*, 2016).

Principle 7: Visual Management

Visual management has been effectively employed in some manufacturing and service industries, however, it has not been considered an essential element of the lean production system (Tezel *et al.*, 2009). This tool is unique to a manufacturing process as it incorporates the entirety of the manufacturing process to promote transparency throughout the company (Steenkamp *et al.*, 2016). Visual control tools and communication goes beyond production management in shop floors as it can be successfully adopted by commercial educational, healthcare, government and other fields as stated by Koskela *et al.* (2016). Visual tools need to be integrated and openly presented in the work environment in such a manner that they are easy to reach and easy to see. There are a few common characteristics of visual management tools which can be named briefly: information needs to be determined ahead of time to prevent information deficiencies, information display needs to be integrated into process elements (space, machinery, equipment) and importantly communications should be simple and should rely a little or not at all on textual information (Tezel *et al.*, 2016).

Principle 8: Use reliable and proven technology

Technological innovations and changes in business environments affect both firms' short-term performance and long-term sustainability. When future directions and options in technology are obscure and uncertain, firms need to formulate an appropriate technology strategy to support their planning for interacting with upcoming future technological developments such as Industry 4.0 (Ghobakhloo, 2018). Technology has evolved rapidly and every organisation wants to be on the cutting edge of technology (Gao and Low, 2014). Technology can be integrated into a lean manufacturing system as long as it supports lean principles and adds value to the process. Digitalisation of production can

be defined as using technology to automate data handling and optimize processes. It is more especially related to autonomous data collection and analysis, as well as interconnectivity between products, processes and people. With the use of advanced enterprise software, this can enable a real-time view of the production process and has a positive association with operational performance (Buer *et al.*, 2021).

Principle 9: Grow leaders who understand the work and live the philosophy

In a paper by Najem *et al.* (2012), organisational culture and leadership influenced the implementation of lean systems in organisations in the past. Culture and leadership work hand in hand as both are important for an organisation to succeed and it has become imperative that leaders pay attention to activities that support continuous improvement (Najem *et al.*, 2012). It is necessary that lean leaders must ensure that culture is serving an organisation's objectives of improvements (Patrick and Alnadi, 2021). People become the most critical part of the system and their willingness to identify and solve problems is what drives continuous improvement (Liker and Hoseus, 2010).

Principle 10: Develop exceptional people and teams

TPS is considered as a culture in the manufacturing industry and any strong organisation should have a strong sense of shared purpose and a strong culture shared by members. This strong culture can be defined as one in which values and beliefs are well aligned with its members and the essence of this pillar is to ensure that exceptional individuals and teams achieve outstanding results (Liker and Meier, 2006). In an article by Deiker (2012), emphasis has been placed on the importance of self-development and its impact on lean manufacturing. The part of the role of culture as one of the TPS principles is often belittled, with management often forgetting that investing in people is equivalent to investing in the company. In an article by Liker and Hoseus (2010), it is clearly stated that the underlying assumption is that carefully selected and developed people over long periods of time will continuously improve processes and ultimately lead to competitive advantage and mutual prosperity.

Principle 11: Respect extended network of partners and suppliers

Part of contributing to society is supporting partners so that they become better and become better suppliers. Challenge is a core value within the Toyota Way and central to the way people and business partners are developed (Meier and Liker, 2006). Given the increased industrial sales and demands of the ever-growing market, it is crucial to develop strong relationships with suppliers and distributors in order for a company to succeed in the market place (Gardener *et al.*, 2004). Initiating partnering relationships with partners and suppliers reduces risks of abnormality and has the prospect of substantial long-term rewards. Through this, partners invest more resources into the relationship and with other partners and suppliers thus increasing the sustainable advantages accruing to both parties (Gosh *et al.*, 2004).

Principle 12: Genchi Genbutsu: Go see for yourself

Genchi Genbutsu can be described as going to the source of the problem or situation and collecting facts and data of the actual site of the work. By applying Genchi Genbutsu, it provides an understanding of how work is actually done and helps in identifying kaizen opportunities, eliminates muda and making it a safe working environment (Sutherland and Bennet, 2007). Conducting a plant walkthrough to see something first hand is simply a practical matter which is one technique not practiced by many manufacturing organisations. There are two main aspects of Genchi Genbutsu, which are firstly that decisions are based on observed facts and secondly, decisions should be put into the hands of the individuals closest to the problem who also have a deep understanding of the problem at the source of occurrence (Like, 2011).

Principle 13: Decisions by slow consensus; implement quickly

This principle is important in making decisions slowly by consensus through the inclusion of people in the problem-identification and solving process (Coetzee *et al.*, 2016). This can be done by improving the problem-solving process by including the process operators. The employees are given an opportunity to make suggestions about solving problems which will make them feel part of a team (Dyk *et al.* 2016). Through this, it is possible to solve problems, make work more satisfying and take organisational performance to an even higher level. This stems down to the involvement of employees

in the continuous improvement process as they influence successful lean transformation and the adaptation of any improvement initiatives (Merve *et al.*, 2016).

Principle 14: Kaizen, Become a learning organisation

In an article by Tekin (2019), Kaizen is a Japanese term that is translated to continuous improvement. It is gradual due to structure changes or technological innovations and it requires the participation of employees at every stage of the process. Even if it is small, continuous improvement is the main element that fulfills the principle of kaizen. The aim is to achieve continuous improvement in costs, quality, flexibility and productivity (Bonavia *et al.*, 2009). Kaizen enables the reduction of costs, which other techniques such as process reengineering or similar methods will not be able to reach, not to mention the contribution to improving physical productivity, reduction of cycle time, quality of products and controls the amount of stock kept by the company (Garcia *et al.*, 2009).

2.4 TPS being the benchmark in the manufacturing environment

Manufacturing companies aim to improve efficiency and obtain better results in the market in which they operate. First-tier suppliers should continuously modify their production systems in line with the lean production philosophy. This is why TPS is the most sought-after production process to implement in the manufacturing industry (Garcia and Sabater, 2009). According to Chiarini *et al.* (2018), TPS incorporated and fostered the principles of people involvement and contribution, empowerment and self-responsibilities. A machine can stop on its own at the detection of an abnormal situation, but the system needs people who are able to quickly respond to each and every problem in a quick and fast manner to determine the root cause of the problem (Chiarini *et al.*, 2018).

2.5 Benefits of implementing this methodology

According to Marksberry (2012), TPS is one of the most benchmarked business improvements strategies in the automotive industry in the twenty first century. The basis of this methodology is that TPS targets processes, rather than whole systems to be more effective and efficient. As stated by Hallam *et al.* (2010), TPS is a well-known continuous improvement methodology in the manufacturing industry and many companies idealise

the TPS concept to gain benefits associated with the implementation such as high-quality product and less waste in processes in the ever-increasingly competitive global markets.

Shrimali and Soni (2017) mentioned that there are many benefits of lean implementation. They are listed as follows:

- Increased capacity at production processes
- Reduced work in progress in processes
- Cycle time reduction
- Guides line or business to a world class organisation
- Cost reduction of processes, materials and labor
- Reduction of fatigue and stress
- Improved continuous improvement culture for the betterment of the company
- Improvement of quality and safety

2.6 Identifying success factors of the implementation of TPS principles

The critical factors that have an impact on the successful application with SMEs were identified by Samontory (2017) and these include member awareness, training systems on lean, team member's devotion and proper leadership, leadership to enhance knowledge among the work force. Lean Manufacturing is widely considered to be proven to be an organisational improvement philosophy, yet the success rate of LM in the industry, especially in the SME's remains relatively low. The human aspect of the TPS methodology and lean is often neglected and that appears to be the main reason why LM is not successfully implemented and sustained (Coetzee *et al.*, 2016). TPS is not just a tool, but rather a culture of many principles that uses the right tool at a specific time (Hallam *et al.*, 2010).

Rose *et al.* (2017) also raised the same sentiments, the "respect of the people" pillar is often given less attention than it should receive, and this is an inherent problem in many manufacturing organisations. Rose *et al.* (2017) mentions that although SMEs aim to implement lean manufacturing, they lack the knowledge to fully adopt the principles correctly, to standardise work and sustain that principle for more than six months. The problem of implementing TPS can be due to a lack of knowledge and understanding of

each aspect of the TPS house. Coetzee *et al.* (2016) further goes on to justify that just as much effort is put into implementing any LM or TPS Principle, the same amount of dedication should be invested in creating a continuous improvement culture. A culture where there is respect for each other, a culture where an effort is made to understand each other and to build mutual trust and at the same time stimulate personal growth of the employees. One of the main techniques used by a Japanese cultured company is the ability to share information from the top to the lowest point in the organisation i.e. the shop floor as this is one of the key factors for maximising individual and team performance.

Dyk *et al.* (2016) further explained that there is a possible way to increase the success of lean transformations and that is to develop higher commitment level from employees, expose employees to better communication, particularly from the highest level downwards and continuously improve processes. Besides strengthening their leadership skills, leaders also need to encourage the employees of the organisation to be innovative and cooperative (Hao, 2015).

Merwe *et al.* (2016) stated that the involvement of employees in the continuous improvement stage is just as important as the implementation of a project or principle. Van der Merwe (2016) also understood that there was no point in implementing a change if employees were not committed to making and embracing change and if this is the case, any transformation will fail. It is apparent that the real success of a lean transformation lies substantially in the hands of the employees who are responsible for implementing and sustaining any change.

In another study by Hailu *et al.* (2017), the role of employees should be taken into consideration when describing the relationship of TPS and TPM, implying that employee's participation and contribution is vital and just as important as the two pillars of the TPS House which are Just in time and Jidoka. An overall culture of continuous improvement needs to be developed for any improvement activity to be successful. The basis and important aspects of TPS is based on continuous improvement and employee's engagement in the identification of opportunities to improve processes and products. Even though this is the case, the people aspect has been solely forgotten and just the continuous improvement aspect has been carried forward (Stadnicka *et al.*, 2017).

Carvalho (2020) described two main sides to the lean philosophy, the visible side and the invisible side. The visible part related to the pillars of TPS and the invisible part related to the basic concept of TPS, treating the workers as human beings and with consideration. Carvalho (2020) further stated the importance of employees and managers in continuous improvement processes and the role they play in changing the routine and culture of a company. Leadership and management, financial capability, employee expertise and organisational culture seems to be the main critical success factors when it comes to lean or TPS implementation (Manson and Hu, 2014). Employees performance and the engagement of people in any production system is essential, despite the size of the organisation.

2.7 Downfalls of the implementation of TPS

Dillon and Shingo (1989) mentioned that it is a mistake to imitate and just go about implementing TPS. External features of the system must be fully understood when applying the TPS principles so that it is successfully implemented. There have been many SMEs that have failed when trying to implement Lean production system's successfully making them reluctant to try again. When an investigation was conducted, barriers in the implementation stage amongst companies are listed as follows, cultural change, education and training and linking quality initiatives to employees were picked up (Yamchello *et al.*, 2014). Some SMEs struggle to fully implement TPS and LM improvement tools as compared to larger companies that have more available resources (April, 2010).

A critical factor that is often forgotten was mentioned by Shrimali (2019), which is the involvement of people. Leadership and management involved, motivation and learning and importantly employee involvement and participation, not forgetting organisational culture change. It is often difficult for companies to move from their traditional production system to now a lean production system (Shrimali, 2019). Newly developed methodologies do not consider the people aspect or even a portion of any strategy when it comes to the employees. This is primarily due to methodologies continuously being developed and being changed into a summarised and easier form, where all the small but important bits of information are being lost and not carried over (Usta, 2016).

Marksberry (2012) further goes on to identify a Type I approach, known as the copycat approach, where companies go on to believe that they can go on to implement Toyota's mature systems to be effective in its implementation overnight. Supplier companies and their managers must be aware of the fact that lean production is a success with other automobile manufacturers, this does not guarantee from the outset that they will also have that success. Supplier companies must be aware that lean production requires investments not just in facilities but also in worker training and time to develop improvements (Garcia and Sabater, 2009).

2.8 Value Stream Mapping

In an article by Chen and Meng (2010), value stream mapping (VSM) assisted in helping people to see and understand the flow of material and information as a product makes its way through the value stream. Aspects of VSM include the customer loop, production control, the supplier and the manufacturing loop, information flow and lead time. This helps the organisation to have a full view of the whole supply chain from the customer requirements to supply delivery. Value stream mapping can be also be described as a graphical way of presenting material and the information flow of a process, company or production system. It also enables the user to view all the tasks undertaken in the process from the start that is, from the purchase of raw material with the delivery of the finished goods to the customer (Trojanowska *et al.*, 2016). This technique was used to achieve the first objective which was to identify the current production processes that characterize a tier-one and tier-two supplier.

Mentioned by Rother and Shook (2003), there are many benefits with using a value stream map. A few are mentioned below:

- Provides common knowledge of manufacturing processes.
- Ties together lean concepts and techniques
- Forms a foundation of an implementation plan (Becomes a blueprint for lean implementation)
- Shows the linkage between material and information flow
- Importantly, a VSM can show Muda (emphasized earlier in this chapter), non-value added and value added elements at each stage of the value stream map

2.9 Quantitative research

The basic elements of quantitative approach to research are measuring things that you can count in a quantity form. Gathering of this data in this approach, where numbers are not considered the final answer and the investigation does not look for a typical response. This method rather investigates individual reactions and responses in a thorough and comprehensive manner (Fryer *et al.* 2018). As mentioned by Rahman (2020), quantitative methods seek regularities in human lives by separating the social world into empirical components called variables which can be represented and accessed through researcher introduced stimuli and systematic measurements. Researched Lieber (2009), quantitative data collection and analysis were found to be less expensive and more confirmatory in nature. Quantitative methods focus on generalizable understandings of population distributions and the relationships between variables. This assists researchers in determining a conclusion of their study undertaken.

2.10 Research gap

The most used principles from the TPS house are standardised work, JIT and Jidoka. The remaining factors, which also contribute greatly to the TPS methodology such as factors that involve developing people, teams and leaders, kaizen could not be found when gathering literature on the TPS methodology. There is less literature that covers the important pillars and factors of the principles of TPS and the methodology and mainly the problem at hand is that there is not much knowledge of TPS being shared in literature for companies to reflect and use. There was also a struggle to find relevant literature between the implementation of TPS between a tier-one and tier-two supplier.

2.11 Conclusion

This chapter focused on literature that has been reviewed and adds value to the Toyota Production System and the 14 principles related to the methodology. This can be used in companies to ensure the implementation of TPS is successful and is sustained in future projects. This chapter commences with the history of TPS and then further goes on to explain the principles of TPS. It also entails and explains additional literature identifying

the success factors and downfalls when implementing the methodology. The next chapter describes the research methodology used in this study in order to achieve objectives.

CHAPTER 3 : RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology that was used to investigate the 14 principles of TPS in each of the chosen companies. It also further goes on to describe the research design chosen as well as the research framework used in this dissertation. A quantitative methodology is strongly used to achieve the desired objectives of this research. In the quantitative aspect, ranking and prioritising of barriers that plays a role in the implementation of TPS in companies allows practitioners to focus on most critical barriers initially and subsequently on the remaining barriers (Yadav and Desai, 2016). This chapter will also diagrammatically show the research framework for this dissertation.

3.2 Research Design

A quantitative research questionnaire was designed and used in collecting data from the tier-one and tier-two suppliers. A sample size of 25 employees from each company was recruited for this research and the respondents were asked if they strongly agree, agree, were neutral in their answers, disagree or strongly disagree. There are 14 pillars of TPS, representing its core philosophies, the methodology commences with identifying the current pillars of the TPS used by a tier-one and tier-two supplier, that is from the following removing imperfections, mistake-proofing, self-reflection, signal, automation with human intelligence, just-in-time production smoothing, continuous improvement, go and see for yourself, build consensus, Kanban, and waste.

A quantitative research methodology was used to collect data from the participants of two suppliers regarding the implementation of continuous improvement as well as their knowledge of the principles. The strengths and weaknesses of the current TPS in a tier-one and tier-two supplier was investigated and compared. Improvement strategies were suggested and implemented as well as developing a framework for future reference for the TPS principles.

3.3 Research Framework

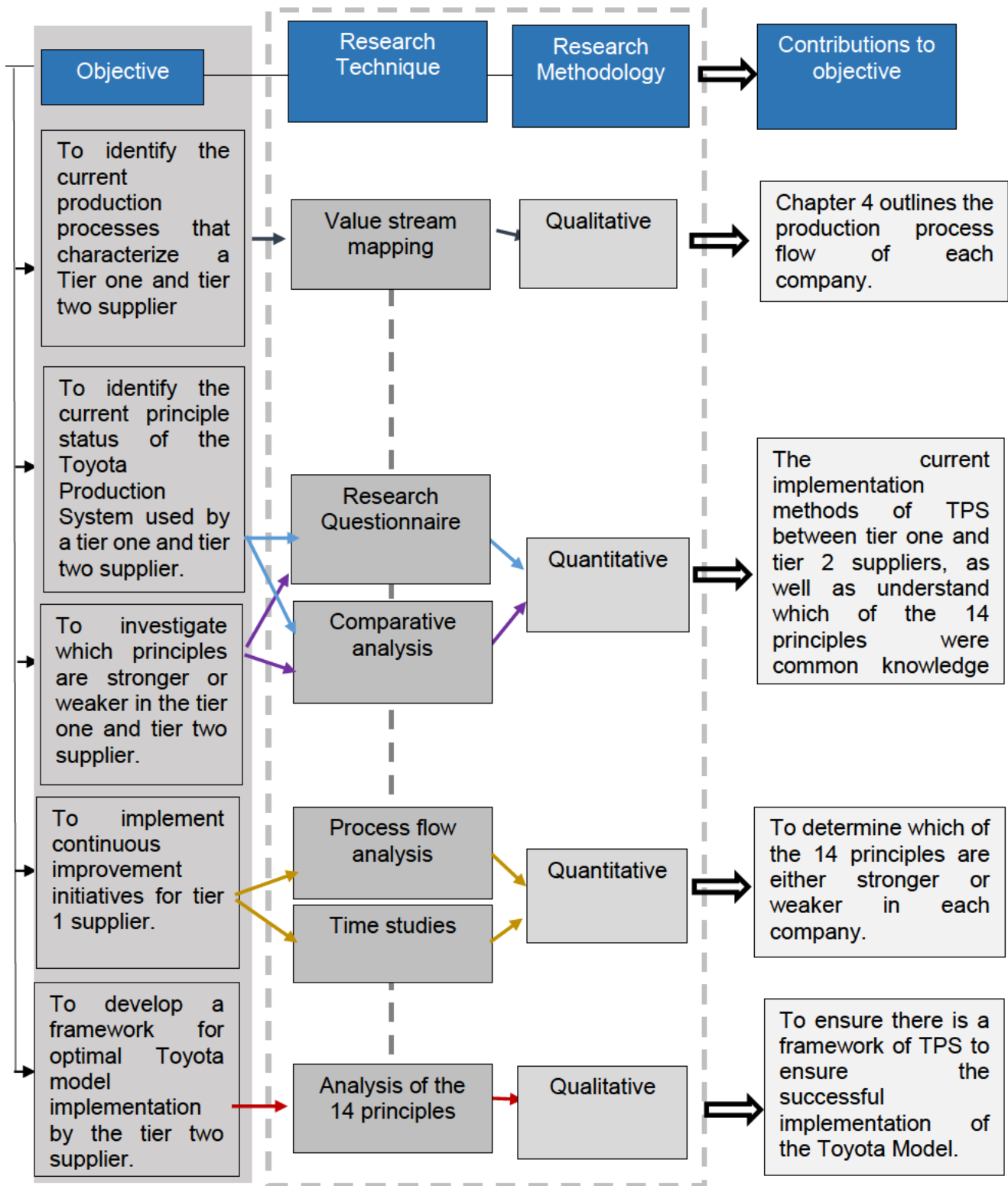


Figure 3.1: Research framework for the model

3.4.1 Methods for identifying processes for tier-one and tier-two suppliers

The first objective of the study was to identify the current production processes that characterize a tier-one and tier-two supplier. This was accomplished through a value stream map to characterize processes of each supplier. For this objective, visual observation of the process is required for the value stream map be drawn up. Kaizen bursts of each supplier which are areas of improvement were also highlighted. Both the tier-one and tier-two suppliers were selected non-randomly as the author has a professional relation with the chosen suppliers.

3.4.2 Methods for identifying TPS principles for tier-one and tier-two suppliers

The second objective of the study was to identify the current principles of the Toyota Production System used by a tier-one and tier-two supplier. This was done using the quantitative analysis from each supplier. From the quantitative analysis, mean descriptive values were calculated and used to describe each principle. Data analysis was conducted through descriptive values of the means, skewness and kurtosis, and an independent sample t-test was used as an inferential tool to establish the relationship between the tier-one and tier-two supplier.

3.4.3 Methods for investigating stronger and weaker TPS principles

The third objective of the study was to investigate the stronger and weaker principles and levels of the Toyota model by doing a comparative analysis using the mean descriptive values extracted from the quantitative study. From the research questionnaire that was used for objective 2, the data collected was used to support the objective which principles were either stronger and weaker in each supplier. A comparative analysis of the implementation of Toyota Production System was then conducted between a tier-one and tier-two supplier.

3.4.4 Methods for implementing improvement initiatives for tier-one supplier

The fourth objective of the study was to implement continuous improvement initiatives for tier 1 supplier. Information for process improvement was extracted via the value stream map, process observation and as well as from the mean statistics found later on in Chapter 5. Two continuous improvements initiatives were identified for the tier-one

supplier; this includes line balancing technique for process improvement in the assembly of automotive components and the implementation of an andon production management system to improve the efficiency of tracking of output scores.

For the line balancing improvement, the first step was to identify the problem and understand the scope of work. The second step was to gather the data about the problem and statistically represent the data to indicate the processes that contribute to the downtime and the bottleneck processes that cause balance delay to ensure correct and precise line balancing can be. Here analysing and interpreting were done using charts, diagrams, graphs and tables. The process flow is shown below in Figure 3.3.

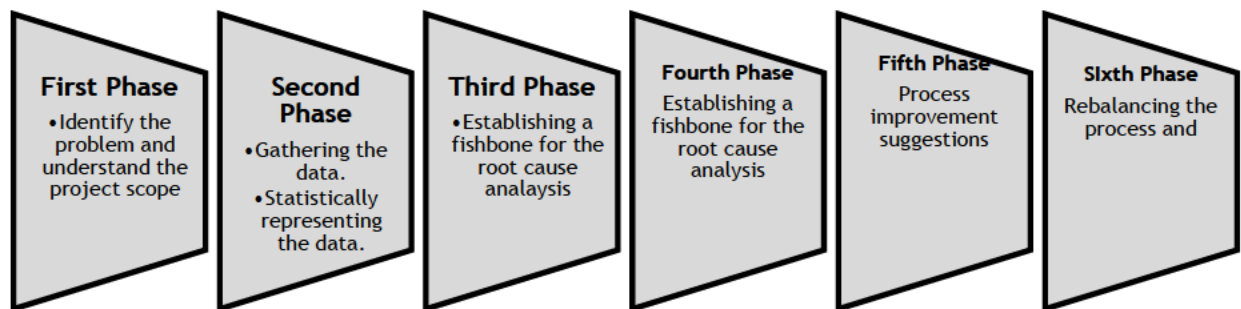


Figure 3.2: Process flow diagram showing the research approach

The third step was to describe the problem accurately after gathering all the data on the problem and drawing a fishbone for the root cause analysis for possible reasons for the issues on the current production line. The fourth step was to identify process muda and suggest improvements to eliminate muda found in the processes set up. The process being studied was then rebalanced by re-distributing the elements between processes. New trial results were then captured and analysed. Actual and target values before and after trials were also compared and analysed to give an indication of the progress. A comparison of the productivity and efficiency before and after implementing and standardising the work per process was also made.

For the implementation of an andon production management system, the PDSA cycle was adapted to follow through the implementation of a proposed andon system to improve the tracking of score keeping of the production assembly line. The PDSA cycle is a four-step model with the first step being the plan or the planning stage. During this stage it is vital to develop a plan in which predictions of outcomes are clearly stated. This is the step

where the “who, what, when and where” is decided. The planning stage of any improvement plays a vital part as this decides the direction of the project. Here the requirements needed for easy visibility of line control were brainstormed collectively with production management before carrying out the implementation. The second step which is the “do” stage consists of the changes or activity identified to be implemented or roll out preferably with a timing plan or schedule (depending on environment). Here the andon is implemented and trialled under production conditions. The third “study” stage requires the leader in charge of the activity to study the implementation. This was trialled for a week and the data was presented to be analysed. In this stage if any further changes are required, it is further investigated and implemented. The final stage of the process is the “act” phase which incorporates any modifications that are deemed necessary from the study stage that may lead to an improvement. Here, full implementation is also carried out to ensure the end users (the quality and production) fully understand how the system works to enable an easier working environment. The process flow of the PDSA cycle is shown below in Figure 3.4.

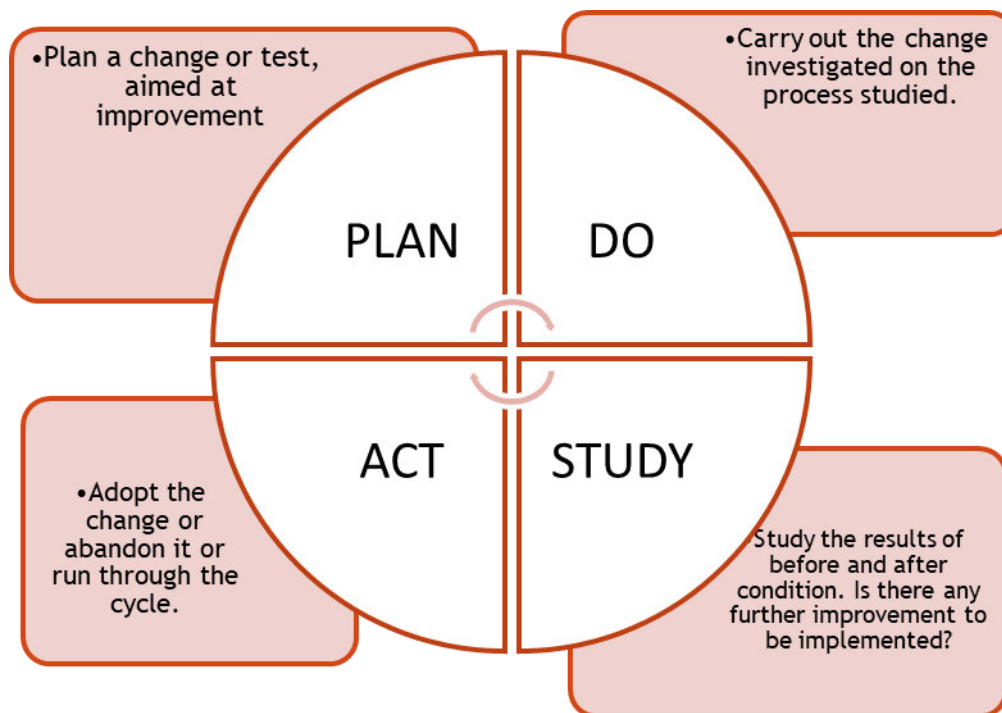


Figure 3.3: The PDSA cycle

3.4.5 Methods for developing a framework for optimal TPS implementation

The fifth objective of the study was to develop a framework for optimal Toyota Production System and the principles of the Toyota model implementation by the tier-two supplier. This framework drawn up would assist not only their tier-two supplier but any supplier which plans to implement any principle of the Toyota model. This model will briefly give direction and step by step instruction for each principle to be successfully implemented. Additional principles were added for easier implementation at each level.

3.5.1 Target Population and Sample Size

A population is defined as the individual in the universe who possess specific characteristic (Lapan et al., 2012). In research, a target population is defined as the comprehensive set of mechanisms out of which a sample for a given study is drawn. The target population for this research is defined to include the engineering team on both sites, maintenance, and production floor members. Managers from direct production, maintenance and engineering were chosen for the questionnaires. Individuals were chosen based on random selection. A sample size of 25 employees was chosen for the questionnaire from the tier-one and tier-two supplier. The sample size for each supplier is shown below in Table 3.1 and Table 3.2. This table also indicates that even though the quantity of each category is different, the same level of employees (Manager to Manager) was interviewed.

Table 3.1 Sample size at the tier-one supplier

Position	Number of Participants
Manager	5
Members/staff	8
Engineers	12

Table 3.2 Sample size at the tier-two supplier

Position	Number of Participants
Manager	3
Members/staff	14
Engineers	8

According to Pearson (2015), this type of research requires responses from individuals about their characteristics, opinions, attitudes or experiences. This is done by asking questions and recording answers. The questionnaire was designed in phases. The first phase focused on questions relating to the respondent's years of experience in their current positions and their educational qualifications. The second phase focused on job-specific questions and relating to their knowledge of the 14 principles of TPS. The 5-point Likert type scale was used to simplify the questionnaire to ensure that it is made as simple as possible for the respondents. The scale was categorised by Strongly agree - 5 points, agree - 4, Neutral - 3, Disagree - 2 and Strongly disagree – 1.

3.6 Administration of Questionnaires

The questionnaires were conducted face to face. Individuals were first informed of the nature of the study and the reason behind it. Individuals were also informed that going under anonymous is also an option. No management was present during the interviews with employees. This was to allow the employees to answer freely.

The management of each company was first interviewed for background information for information sharing and knowledge, followed by the survey with the employees. The duration of each questionnaire was briefly between 6-7 min. Any questions that were not applicable to the individuals, were not answered. This was communicated with the individuals that were participating in the study.

In an article by Curasi (2001), online data collection restricts individuals who have access to the internet in part taking in a research. While face to face interviews, participants are more spontaneous and speak greater lengths and provide relevant information without the need for explicit prompting (Irvine, 2011).

3.7 Inclusion and Exclusion Criteria

The population selected for this study did not discriminate in age or gender. The respondents that were selected were experienced in their field and understood the nature of this study. The sampling strategy aimed to ensure useful and informative feedback is received which contributed to the objectives of this study.

Non-probability sampling was used in the sampling of this study. This can be described as non-random, subjective and purposive as this requires criteria where sampling as compared to probability sampling. The overall aim is to select a sample with a wide range. Samples from the population are not selected randomly but in a deliberate conscious manner.

Inclusion Criteria

- Individuals must be directly involved in implementing Toyota Production systems or working in processes where TPS improvements are done.
- Must contain an adult population.
- Only respondents who had given permission us was interviewed.

Exclusion Criteria

- Participants demographic or geographic information does not play a role in the research. Personal information of each individual was not a concept of this study; thus, this was not a factor when Individuals were asked to be a part of this study.
- Individuals with less than two years of work experience were excluded as experience is required to implement and observe the surroundings as well as to monitor the principles of TPS being implemented and observe possible shortfalls.

3.8 Reliability and Validity

A selection criterion was applied to increase the reliability and validity of the study results. This was to ensure that both organisations selected had the same characteristic to ensure data collected ties in with the research objective. The criterion and description of each criterion is explained in Table 3.2 below. The purpose of each criterion is also explained. This is to ensure that conclusions drawn reflect accurately what was being studied.

Table 3.2 Reliability and Validity of data collection criteria

Criterion	Description	Purpose
Organisation type	Organisations participating to be manufacturing organisations.	To ensure both companies are studied based on the same environment.
Industry	Organisations must operate in the same industry: Automotive industry.	To avoid conducting a study in different environments.
TPS Implementation	Both companies have and continue to implement TPS methodologies aspects.	To ensure that the questionnaire and survey are relevant to the environment.

3.9 Pilot Study

A pilot study was conducted to test the validity and reliability and user-friendliness of the questionnaire that was designed for this research. A sample size of five from the target group was chosen for the pre-test of the study. Preliminary analysis of the data collected through the pilot study can be done to ensure that the data collected would answer the objectives of the research.

3.10 Data Analysis

Data analysis refers to the categorization, ordering, manipulating, ordering, and summarization of the data and relating it in significant terms (Miles *et al*, 2014). Answers from the survey will be quantified and shown graphically in chapter 5. Answers from the interviews assisted in understanding the strengths and weaknesses of implementing TPS in each of these environments. Feedback from both the tier 1 and tier 2 suppliers was used in developing a framework for the optimal implementation of TPS in SMEs. SPSS (Statistical Package for Social Science) is a software package used in analysing data. These software programs can be used in organizing, analysing and finding insights in unstructured or qualitative data like interviews, open-ended survey responses where deep levels of analysis on small or large volumes of data are required.

3.11 Ethical Considerations

This study was conducted following the full ethical approval from Durban University of Technology, Institutional Research and Ethics Committee (IREC). This letter was first received before consulting with any company and is attached as Appendix D. Appendix I shows a certification that the researcher undertook when protecting the human participants in any given research. This letter of permission is attached as Appendix A. Confidentiality is a basic ethical principle while anonymity is one way in which confidentiality can be maintained. Confidentiality is the researcher's management of private information shared by the participants, which must not be shared with others without the authorization from the participants.

For this research, the participating respondents from the tier-one and tier-two supplier was informed about the background and purpose of this study. Permission was then granted from tier- one supplier and is attached as Appendix B as well as the tier-two supplier, which is attached as Appendix C. The cover letter that was shared with the respondents is attached as Appendix F and G at the end. This form was first handed to each respondent before any questions was asked or survey done. They then thereafter decided whether or not to participate in this research survey. Applicants that decided to participate in the survey were then handed a consent form. This form gives us permission from the respondent agreeing to be a part of this research. This form is attached as Appendix G. Each applicant was informed that they can go under anonymous should they feel uncomfortable in disclosing their feedback.

3.12 Conclusion

This chapter focused on the research methodology and techniques used in the study. This chapter also includes and explains the quantitative aspect of this research as well as the research framework that was adopted. A deep analysis of each technique is also explained and indicated on the research framework of how each technique ties in with the research objective of this thesis. A quantitative research methodology was adopted with quantitative survey. This chapter also goes on to describe the sample size, inclusion and exclusion criteria and the ethical considerations for this research. Criteria for each

company that was chosen for this study was also explained to ensure the environment in which this study was conducted was of the same nature to avoid data being crooked. The methods used to ensure that validity and reliability of the study were also explained to ensure that data collected speaks into the research objectives of this dissertation. Chapter 4 will explain the current production processes for the tier-one and tier-two suppliers chosen for the research.

CHAPTER 4 : PRODUCTION PROCESSES AT CASE STUDY COMPANIES

4.1 Introduction

The first objective of the study was to identify the current production processes that characterize the tier-one and tier-two supplier. This chapter will use a value stream map to describe the production and manufacturing process at each company chosen. Value stream maps (VSM) can be described as an effective tool for the practice of lean manufacturing. A value stream map first starts of by showing the material and information flow on the current state of how the manufacturing process operates (Rahani and Al-Ashraf, 2012). In this chapter, the characteristics of the Japanese based company and the SME will be explained as well as shown on a value stream map. This research was conducted in two manufacturing organizations which were non-randomly selected. This was done by visual observing the suppliers manufacturing process from start to end to extract information as well as to draw up the value stream map to determine areas of improvement.

4.2 Characteristics of the selected suppliers

The characteristics for each supplier are listed below in each table.

Table 4.1 Characteristics for each company

Characteristic	Tier-one	Tier-two
Number of employees	1200	400
TPS implementation	Yes	Yes
Type of Business	Production/Manufacturing	Production/manufacturing
Service or Manufacturing	Manufacturing	Manufacturing
Industry	Automotive	Automotive

The table above describes the characteristics tier-one and the tier-two supplier. The tier-one supplier has a volume of 1200 employees on their site as compared to the tier-two supplier which has approximately 400 employees at their factory. Both suppliers have

implemented aspects of TPS at their production processes and throughout the company. They are both also in the same manufacturing sector of automotive and is a manufacturing environment.

4.3 Tier-one supplier

An automotive component manufacturer, Toyota Boshoku South Africa is a Japanese based company based in Amanzimtoti, Durban. This automotive component manufacturer produces both interior and exterior products for their one customer, Toyota South Africa. Parts produced are namely interior car seats and side door panels for the IMV Hilux and the new C-SUV Hybrid vehicle. Being a Japanese based company, this company follows just in time (JIT) as their source of supply of parts to their customer. This means that the manufacturing processes only produces what the customer orders in that time.

Planned production and what variant to produce in advance is not determined at this manufacturing company, daily requirements of products are sent to the factory as a three-month forecast. This is sent to all production leaders to prepare their processes for the incoming data. This information is then reviewed, and quantities required by the customer is then sent to supplier to ensure on time delivery is ensured to fabricate and manufacture a component. This information is also sent to the suppliers of the company so that they are formally aware of the production requirements. Once material and supplies are in plant, the manufacturing process begins up until the final product goes through final inspection completed by a quality department and then gets delivered to the final customer. This company follows a Heijunka process (heijunka refers to the leveling of production, aimed at improving the flow of a process to better match customer demand, reduce waste, and decrease or quit batch processing) throughout the factory.

4.3.1 Value stream map for Tier-one Supplier

The company's value stream map is shown below in Figure 4.1. This shows the overview of the processes from the customer requirement to the manufacturing processes.

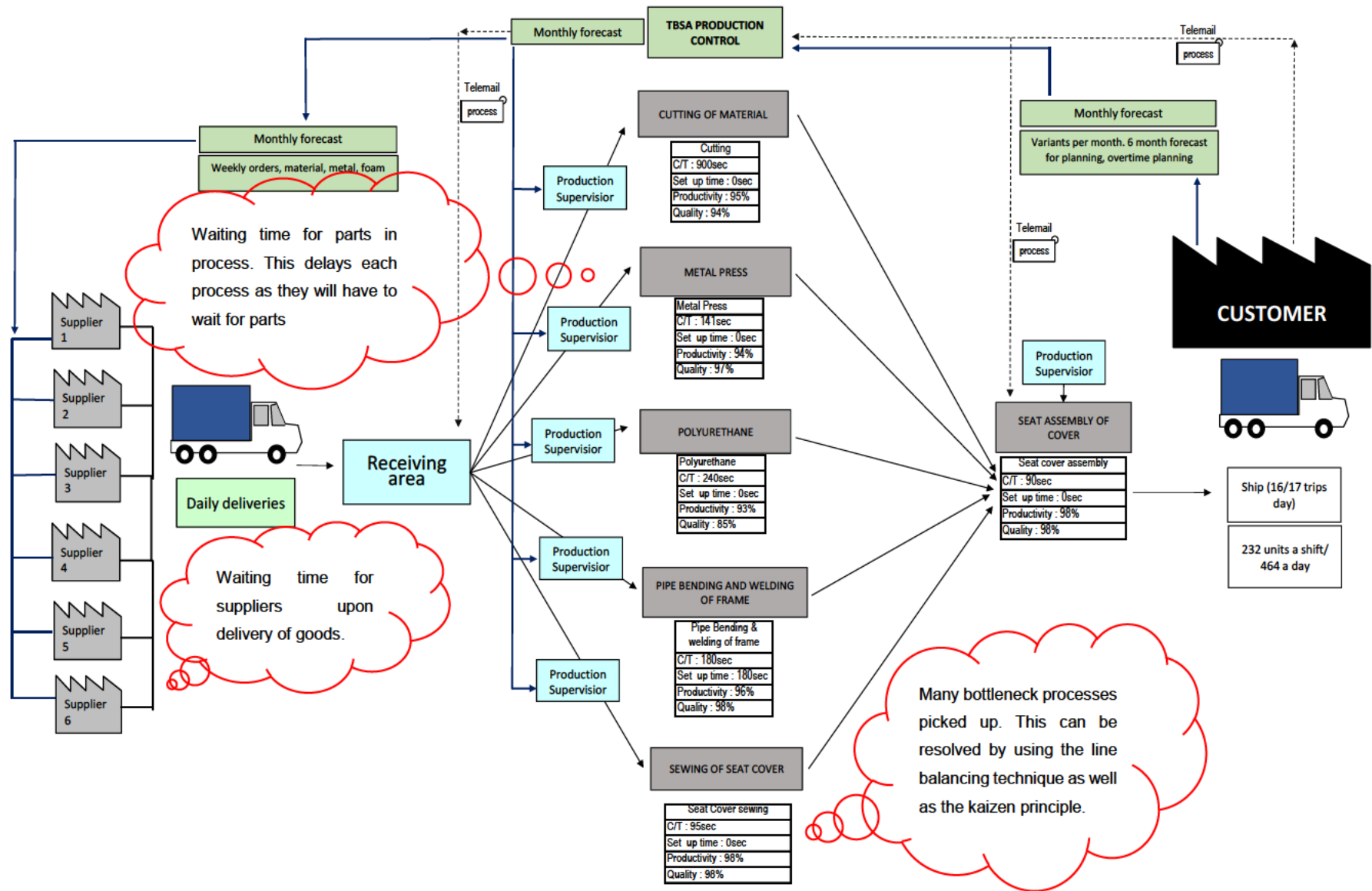


Figure 4.1: Value stream map of the tier-one supplier

- The production instruction to this production line is through a Kanban card or telemail (same as Kanban card).
- This Kanban card of each variant is a direct request from the customer at what they are building at their plant in that moment in time. This Kanban card gives the instruction to the start of the manufacturing process to ensure the instruction is ready at the start of the line.
- This kanban instruction is also sent to the sewing cover line as well as the final seat assembly line. As the kanban is picked up by the team in sewing, parts are picked and sewn according to the requirement of the customer. The total cycle time for a sewing cover to be complete is 95 seconds.
- The Polyurethane, cutting and welding department build stock to buffer. These processes do not have to follow the telemail / Kanban system as they build stock per department of eight hours. This means that when the final seat assembly line pulls parts, each department replenishes the stock. Stock at each process is kept at eight hours and is a standard throughout the plant.
- Once the final seat assembly line receives the instruction, parts are picked from the different departments to manufacture this part. Once all parts are collected, it takes a total of 90seconds for the entire seat to be manufactured.
- These seats are then placed on a conveyor in sequence and then transported to the customer. Total cycle time from the factory to the customer is 30 minutes.

4.3.2 Kaizen bursts for Tier-one supplier

After observing and drawing up the value stream, there are many areas of improvement and kaizen opportunities in their processes. They are discussed below:

1. The processes at the tier-one supplier are characterized by too much waiting time, operators waiting for parts and materials to complete their job. there are no alert systems for on time delivery at their processes.
2. Volume stock between the company and the customer is less than a day. This could be a critical item in the case there is a breakdown or a part shortage supply from suppliers. There should be increased stock between the tier-one and tier-two supplier.

3. It was observed that some of the processes do not meet production targets and there are many bottlenecks in their cover assembly production line. This can be resolved by using the kaizen principle as well as line balancing technique.

4.4 Value stream map for tier-two Supplier

Aeroklas Duys, formerly known as Duys Component Manufacturers Pty Ltd. (DCM) was established in 1991 and is a member of the Duys Engineering Group, which is solely owned by the Duys family. Aeroklas Duys is accredited to the ISO 9001 Quality Management System. These divisions are situated in Progress Road, New Germany just outside of Pinetown in Kwa-Zulu Natal, South Africa. This automotive company manufacturer branded components for companies as well as fitment centers and dealerships. Components such as roof rails, side steps, quantum driver guards are just some of the many different components manufactured at Aeroklas Duys.

The sales department presents the customer requirements from make to order requirement. The production planning department creates the production schedule on high volume parts. This information is then sent to the relevant manufacturing department which indicates the due date and quantities. The procurement department then purchases material using the production schedule and places orders with this information. This plan is analysed by the production managers and a plan is created for each individual department.

4.4.1 Tier-two company Value stream map

The company's value stream map is shown below in Figure 4.2. This shows the overview of the processes from the customer requirement to the manufacturing processes and finally to the customer.

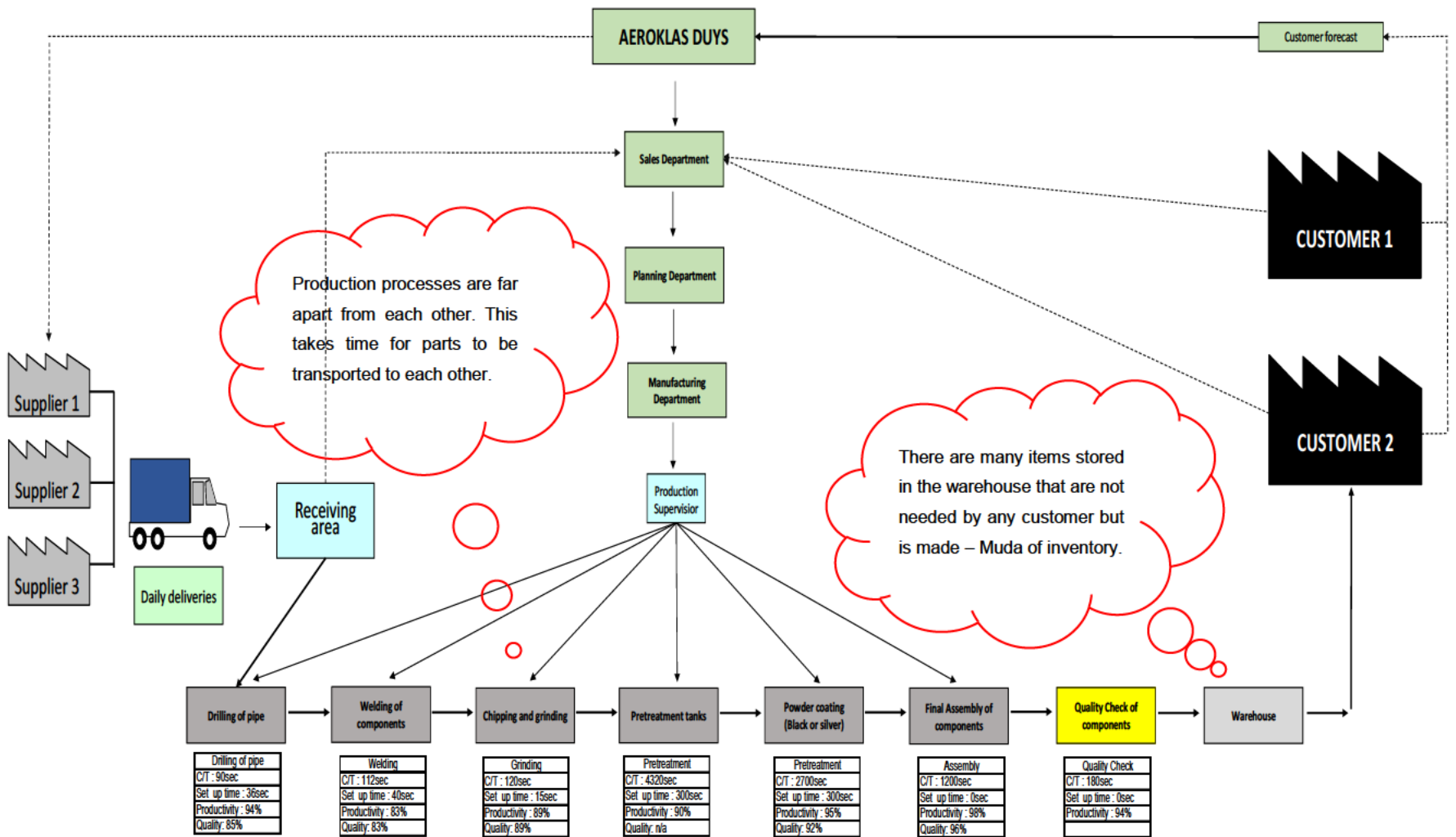


Figure 4.2: Value stream map of tier-two supplier

- Production managers and supervisors then plan and allocate resources to each department. Supply chain and logistics then issues material to production jobs.
- Production leaders then align their processes to manufacturer components to the specified due date needed by the customer. This is also according to the production plan.
- Raw materials are delivered from suppliers on a daily basis. These materials are first cut and then drilled at the department. Some of these parts go to welding or straight to assembly. This is to ensure that there is easy welding and assembly at the final process. At the welding station, this where the parts are assembled together by the welding operation. It is a critical stage of assembling because once the part is assembled it is very difficult to disassembly if it is rejected. There are also plasma welding machines and manual welding operations under this sub department.
- After the welding operation, all components are going through a chipping and grinding operation. This is to ensure that there are no weld spatter and that the welding operation followed the critical weld points. This is checked by the quality department. If a component is not chipped around the weld point, this is then considered rework and set back to the grinding and chipping operation.
- Once the parts have been checked, all parts then go through the next department which is known as the Pre-treatment tanks. There are seven tanks in this operation, which components go through to ensure that all grease and chemicals are removed so that the paint is applied to the components successfully. The seven tanks which consist of: degreaser, rinse, acid, rinse, zincoline, rinse and rust stop are controlled by one manufacturing member with a hoist transferring parts from one to the next.
- After pretreatment process, components are then sent to powder coating department for resistance to cracking, and rust prevention. Here with a spray gun, powder is sprayed onto the components either a color of black or silver, depending is the component being manufactured. Parts are then transported to the drying oven for the powder to melt for a shiny black coat on components.

- Parts are then transferred to the relevant assembly departments. At this stage, parts are carefully assembled to form the final product requested by the customer.
- All parts then go through a quality gate before leaving the department.
- Once the finished goods are then analysed and passed, it is then stored in the finished goods warehouse and the information of the product is put into the system each time a component is manufactured.

4.4.2 Kaizen bursts for tier-two supplier

There are many areas of improvement at the tier-two supplier, although the organisation has smaller volume base, there are many kaizen opportunities to ensure their processes are efficient as possible and that there is no wastage from their processes.

1. There is a long distance for parts to be transported between operations. This process can be made more efficient if a more effective layout would be drawn up. An L shape or conveyor system should be implemented to provide a more efficient process as well a method to increase score output.

2. It was also found that there were also huge amounts of stock in the large warehouses that had been manufactured 3 months ago. As inventory is part of the 7 wastes in the manufacturing process, it would be better if a kanaban system be implemented or a telemail system to only produce what the supplier requires when they require it.

4.5 Conclusion

The aim of this chapter was to outline the background of each company mentioned in this dissertation. A VSM described the manufacturing processes from raw material up until the final product is manufactured. A VSM of each company and their planning of their manufacturing process was also depicted to give the reader an understanding of the processes that defines each company. Each manufacturing company and their processes were also described as well as certain information of each process within the company. The next chapter discusses and displays the descriptive results as well as the data values collected and calculated from each company.

CHAPTER 5 : RESEARCH RESULTS AND DISCUSSION

5.1 Introduction

This chapter focuses on the research methodology presentation and discussion of the research results. The key items highlighted in this chapter are that of the four levels which can be dissected into the 14 principles of which are stronger or weaker in each company. Responses from the questionnaires are also shown statistically and were tabulated for a comparative analysis. The data from both sites were also captured separately to simplify the interpretation of the statistics. Responses from the questionnaire from each company was compared with each other and discussed. By utilising descriptive statistics, the data collected was analysed and provided an interpretation of the mean, skewness and kurtosis of each principle.

5.2 Demographics

The demographics are shown from both the tier-one and tier-two supplier in Table 5.1

Table 5.1 : Occupation of research applicants

Occupation	Frequency
Manager	7
Maintenance Personnel	8
Production members	15
Engineers	20
Total	50

Table 5.1 shows the occupation of the research participants, indicating that the majority of the respondents were members from production manufacturing process and process engineers in the company.

Table 5.2 : Gender of research participants

Gender	Frequency
Male	34
Female	16
Total	50

Table 5.2 displays the gender split of the research respondents that participated in the research. The responses were characterized by 34 male participants and 16 female participants whom of which contributed to the study from each company.

Table 5.3: Age of participants

Age Category	Frequency
20 – 25 years	6
26 – 35 years	16
36 – 45 years	23
46 – 55 years	4
56 – 65 years	1
Total	50

Table 5.3 indicates the age categories for all the participants. The results show that a large number of participants fell in the age range of 26 – 35 years and 36 – 45 years. While there was one individual in the 56 – 65-year age interval and 4 participants between the 46 – 55-year gap.

Table 5.4: Work experience of research participants

Work experience	Frequency
2 – 5 years	24
6 – 10 years	9
>10 years	17

Table 5.4 displays the work experience amongst the participants. The results show that 24 of the participants between 2-5 years, 9 workers have more than 6 -10 years of experience and lastly there are 17 participants who have more than 10 years of experience.

5.3 Results on principles for the Pyramid model for the tier-one supplier

The second objective of the study was to identify the current principles of the Toyota Production System used by a tier-one and tier-two supplier. Quantitative analysis of the

data captured from the tier-one supplier is explained below with descriptive statistics for means, skewness and kurtosis. Values for all questionnaire items are explained below. All the means of the questionnaire items are all above 3. This indicates that the individuals whom participated in the study agreed with the statement asked.

5.3.1 Philosophy level

The philosophy level, which is the base of the pyramid is characterized by one principle which is management decisions based on long term philosophy even at the expense of short-term financial loss. This explains that management should think about the long-term requirements of the company before moving forward with any decision.

The participants were asked to express their perception around the statement “Toyota Production System (TPS) can improve profitability, process and quality in a business”. This is shown graphically on a bar graph in Figure 5.1 and from the statistics we can see that 28% of the respondents agreed with the statement, while 72% of the respondents strongly agreed.

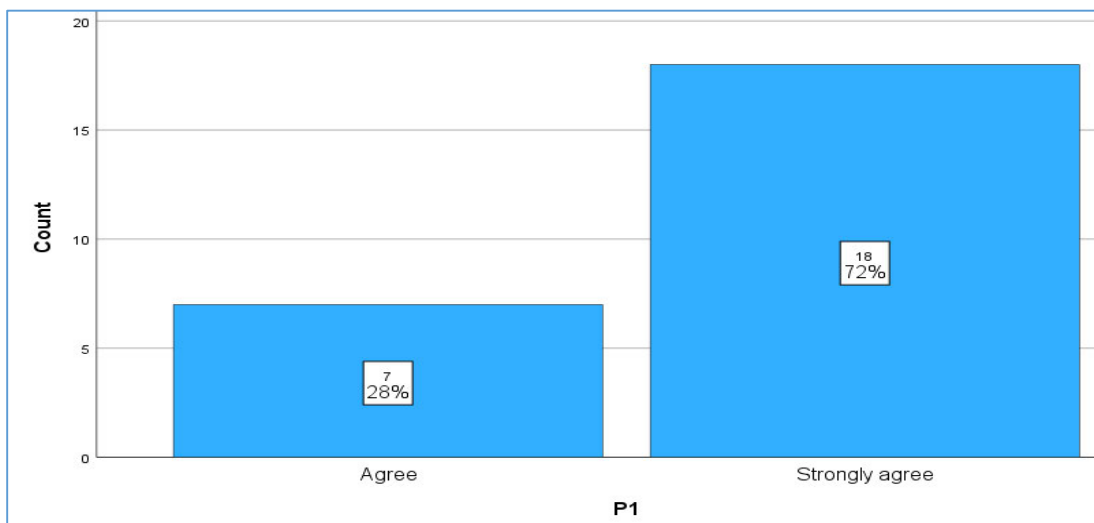


Figure 5.1: Statistics for Principle 1

Table 5.3 shows the descriptive statistics of the data. From the data below, we can see principle 1 has the mean statistic of 4.7; skewness is -1.044 while kurtosis is -0.998. The skewness value is negative, an indication that the distribution lies more to the right of the

median, revealing that the participants agree with the statement for this principle of the questionnaire. The negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

Table 5.3: Statistics for Philosophy level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P1	4.720	5.000	0.458	-1.044	-0.998

5.3.2 Process level

The second level of the Toyota way model is the process level. At the process level, principles affecting the manufacturing process are part of this level. This level consists of one-piece flow, pull system, Heijunka, Jidoka, standardised work, visual management and the use of reliable technology. The statistic of this level is discussed below.

5.3.2.1 One-piece flow (waste elimination)

Respondents were asked to express their perceptions on the one-piece flow principle. The statistics show that 52% agreed that their company has a continuous improvement culture and continuously improves their process, whereas 40% strongly agreed and 8% were neutral. This is shown graphically in Figure 5.2. Table 5.4 below shows the statistics of the data, displaying an item mean statistic of 4.3; skewness is -0.345 while the kurtosis is -0.527 indicating that respondents overall agreed with this statement.

Table 5.4 : Statistics for principle 2 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P2	4.320	4.000	0.627	-0.345	-0.527

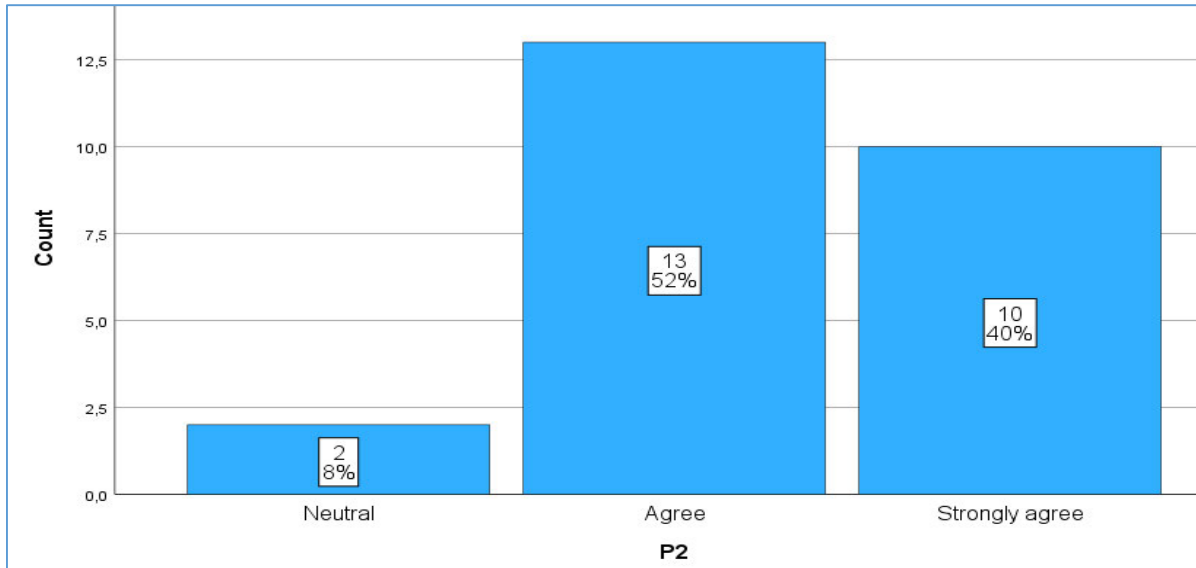


Figure 5.2 : Statistics for Principle 2

5.3.2.2 Use pull system to avoid over production

Respondents were asked to express their perceptions on the pull system which is principle 3. The respondents were also asked if their company uses a pull system to avoid overproduction as well as if this methodology, the pull system works for the company. The statistics show that 44% agreed and 52% strongly agreed whereas 4% were neutral on this principle. This is shown graphically in Figure 5.3. Table 5.5 below shows the statistics of the data, displaying an item mean statistic of 4.3; skewness is - 0.345 while the kurtosis is -0.527 indicating that the respondents agreed with both these statements and was in favour of these principles.

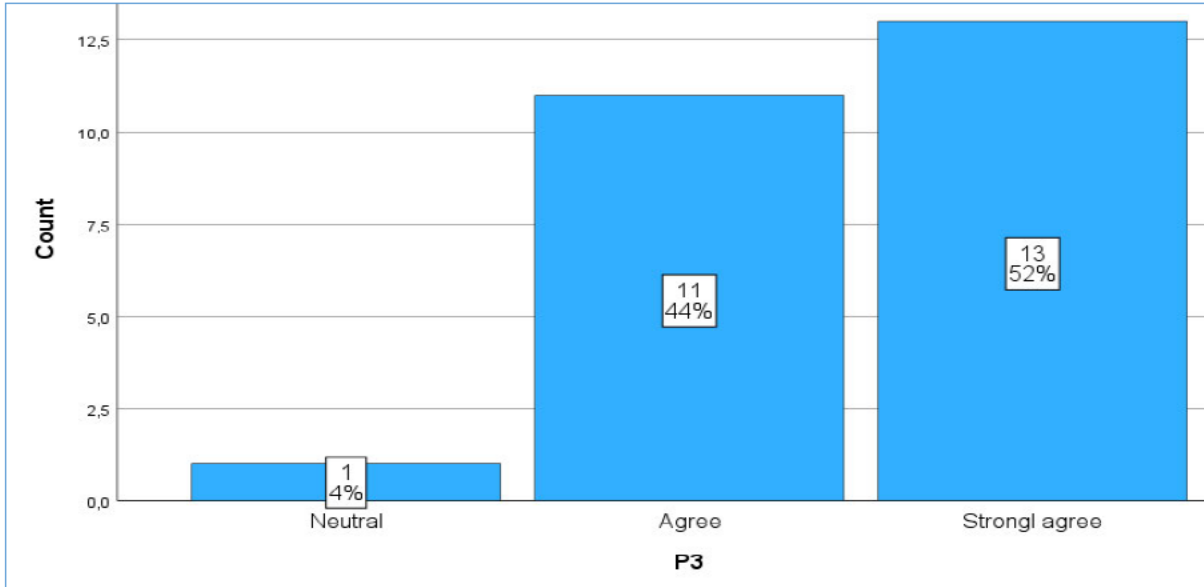


Figure 5.3: Statistics for Principle 3

Table 5.5 : Statistics for principle 3 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P3	4.480	5.000	0.586	-0.592	-0.540

5.3.2.3 Heijunka

Respondents were asked to express their perceptions on Heijunka, is principle 4. The respondents were also asked if their company makes it known of the seven types of waste as well as if there are ongoing activities in the workplace. The statistics show that 36% agreed and 60% strongly agreed whereas 4% were neutral on this principle. This is shown graphically in Figure 5.4. Table 5.6 shows the statistics of the data, displaying an item mean statistic of 4.5; skewness is -0.936 while the kurtosis is - 0.003 indicating that respondents mostly agreed with this statement.

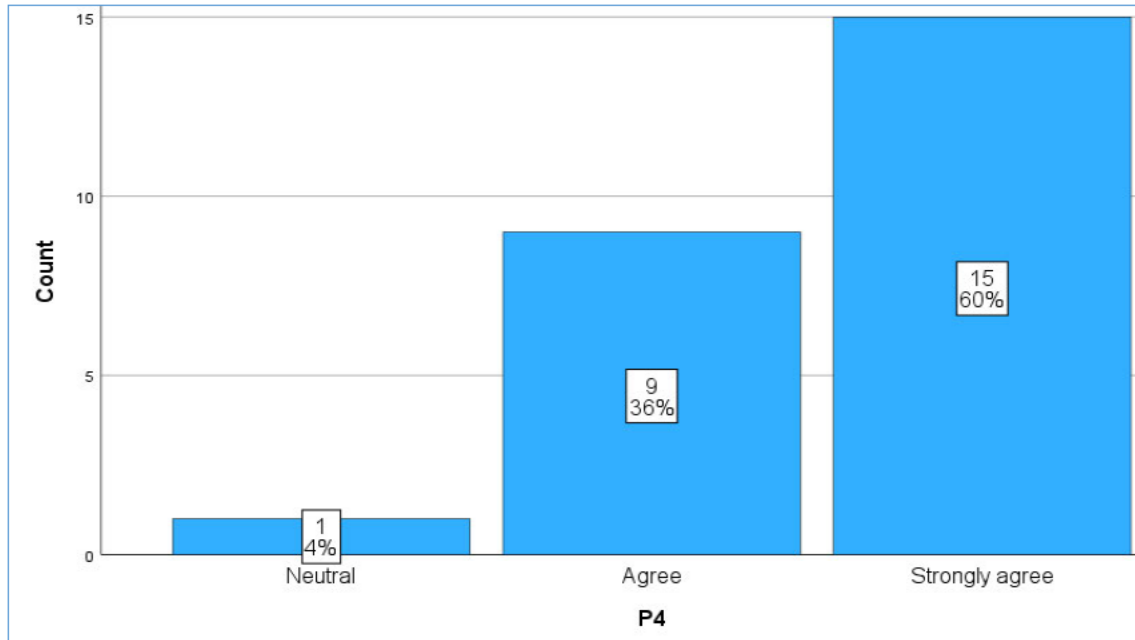


Figure 5.4 : Statistics for Principle 4

Table 5.6 : Statistics for principle 4 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P4	4.560	5.000	0.583	-0.936	-0.003

5.3.2.4 Jidoka – Build in quality

Respondents were asked to express their perceptions on Jidoka, a concept also known for building quality into a process. This is principle 5 from the process level. The respondents were asked to express their perception concerning this principle and if quality is at its best and delivered to the customer first time around. The other statement which was asked is that if there are alert systems in the manufacturing process to identify defects at the same time. The statistics show that 44% agreed and 52% strongly agreed whereas 4% were neutral on this principle. This is shown graphically in Figure 5.5. Table 5.7 below shows the statistics of the data collected, displaying an item mean statistic of 4.48; skewness is -0.592 while the kurtosis is -0.540 indicating the respondents agreed with the statements. The negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

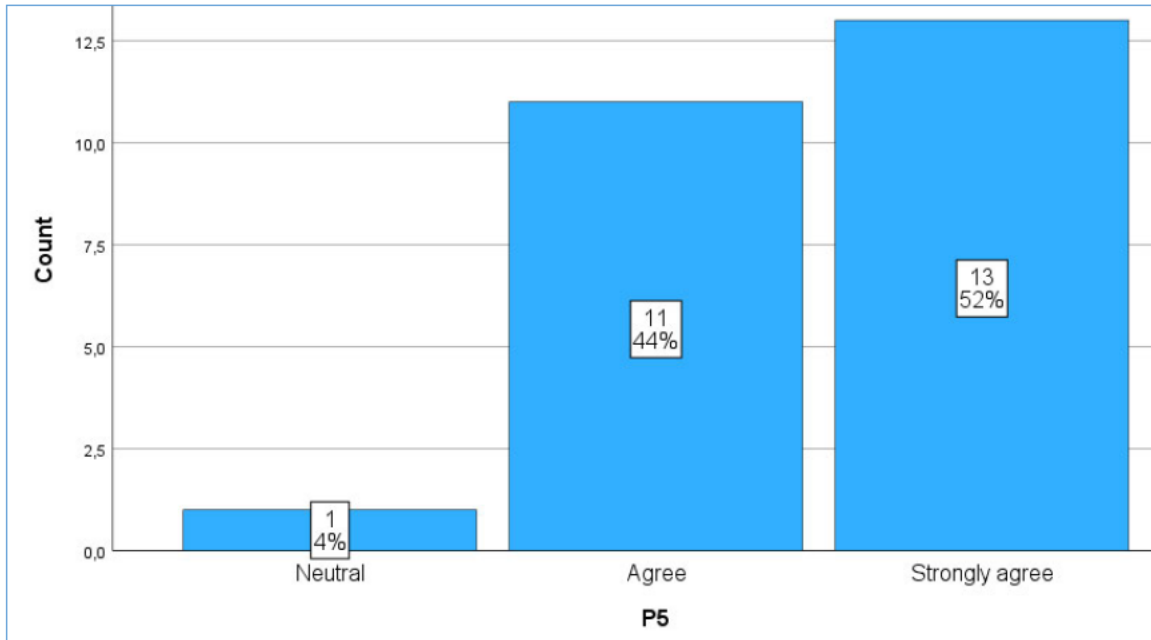


Figure 5.5 : Statistics for Principle 5

Table 5.7 : Statistics for principle 5 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P5	4.480	5.000	0.586	-0.592	-0.540

5.3.2.5 Standardised work

Standardised work can be described as documenting the steps of a job and the sequence in which it should be done rightfully. The respondents were asked if standardised work was part of their daily routine at their workplace. The other statement that was asked if respondents had measures in place for standardised work. From the respondents, the statistics show that 56% strongly agree, 36% agree and 8% were neutral in their answers. The statistics for principle 6 display a mean statistic of 4.80; skewness of - 0.895 while the kurtosis being - 0.152 indicating that majority of the respondents agreed with the statements. A negative kurtosis value points out that the distribution has a lighter tail than the normal distribution. This is shown below in Figure 5.6 and Table 5.8 respectively.

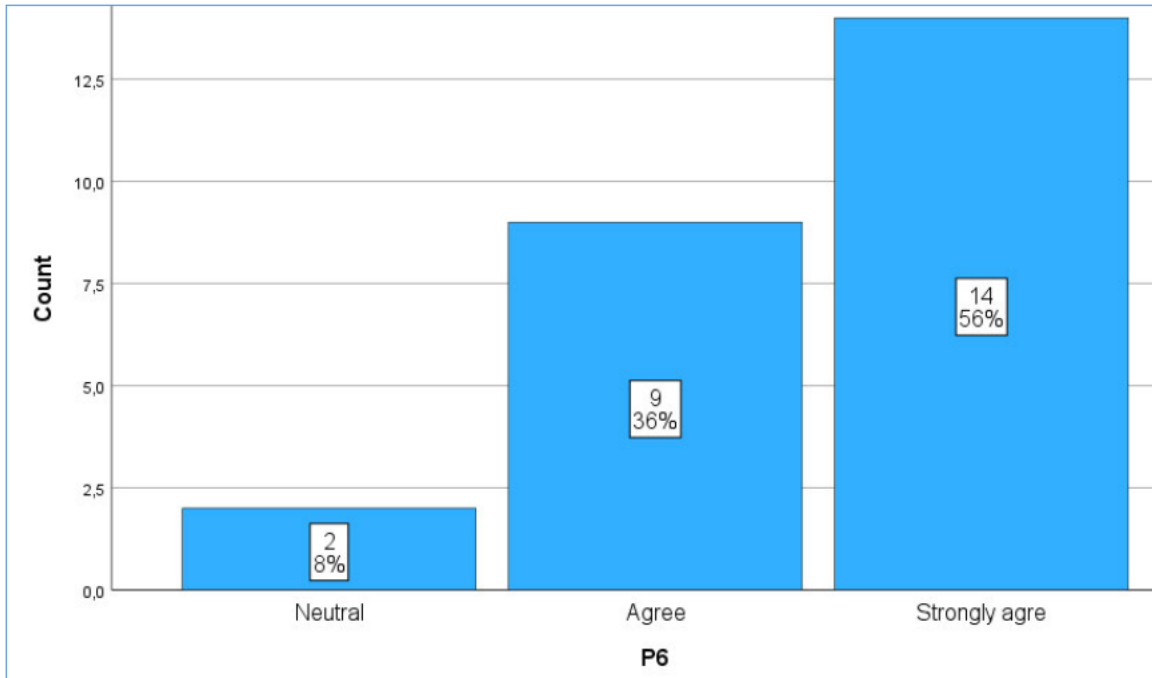


Figure 5.6 : Statistics for Principle 6

Table 5.8 : Statistics for principle 6 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P6	4.480	5.000	0.653	-0.895	-0.152

5.3.2.6 Visual management

Work instructions and procedures play an important part of the TPS model. It is vital that visual controls are at the process as this can determine if there is any deviation from the process. In the case that there is any deviation, it is easy for the process owner, to refer and revert to the process. For this pillar, the respondents were asked if there were visual controls at the process to prevent deviation from the process. As shown in Figure 5.7, about 40% of the respondents strongly agreed with this statement, highlighting that there are visual systems in their processes, 44% agreed, 12% of the respondents responded neutral and 4% disagreed. These statistics show that of a mean of 4.0; skewness is -0.899 and a kurtosis of 0.651. The skewness value is negative, an indication that the

distribution lies more to the right of the median while the kurtosis being a positive value indicates a slightly steeper distribution. These values are shown in Table 5.9.

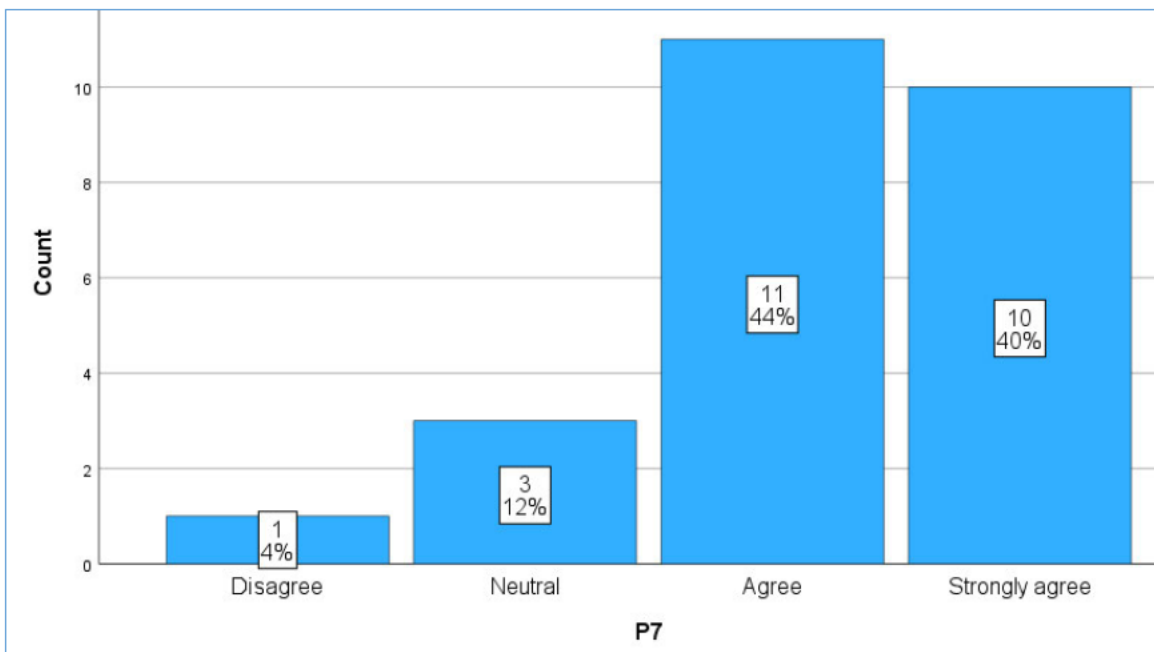


Figure 5.7 : Statistics for Principle 7

Table 5.9 : Statistics for principle 7 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P7	4.200	4.000	0.816	-0.899	0.651

5.3.2.6 Use reliable and proven technology

Visual controls can also be described as using technology in showing and displaying production results or notifications. By using these controls, we can manage processes easier. Through visual management and using reliable and proven technology, production line leaders and managers can manage the process more effectively and efficiently. By using proven technology, we can improve productivity and production processes. For this pillar the respondents from the tier-one company were asked if their company had cutting edge technology to improve their processes. They were also asked if their company is currently investigating further technology to improve their business processes. The

statistic from this pillar is shown below in Figure 5.8. For this pillar 56% agree with this statement, 40% responded neutral and 4% disagreed. This is shown graphically below in Figure 5.8. The statistics for this pillar as also shown below in Table 5.10. This table displays a mean of 3.520; skewness of - 0.759 and a kurtosis of - 0.322 indicating that the respondents of the study mostly agreed with this statement. A negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

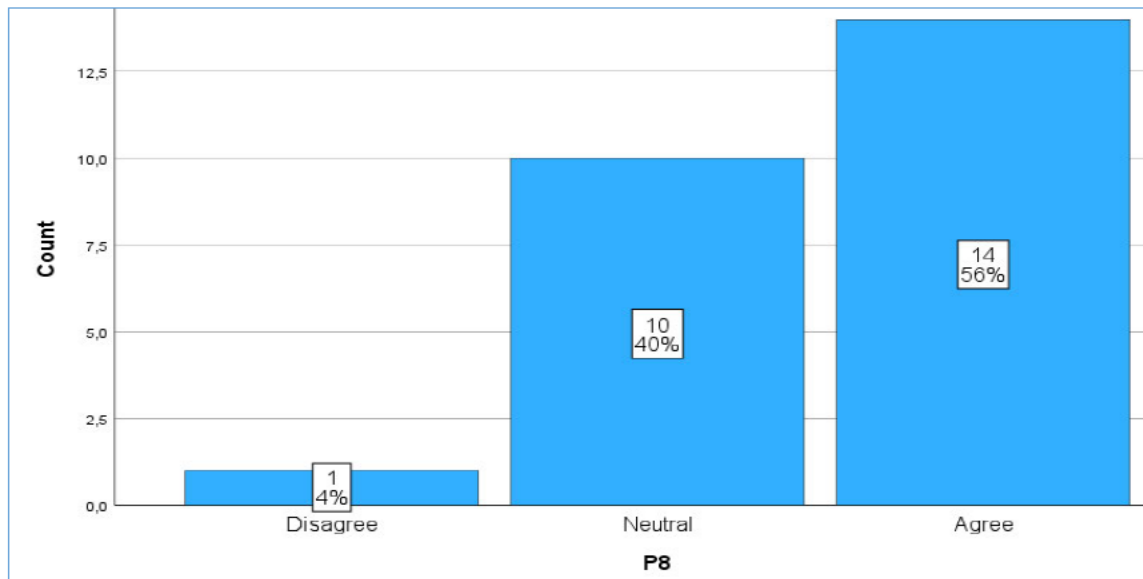


Figure 5.8 : Statistics for Principle 8

Table 5.10 : Statistics for principle 8 of the process level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P8	3.520	4.000	0.586	-0.759	-0.322

5.3.3 People and partner level

This level pertains to people and partners of an organisation in which the Toyota model is implemented in. This level consists of three pillars, which are growing of leaders, principle 9; developing exceptional people and teams, principle 10; and principle 11, developing not only inside the organisation, but the Toyota model also emphasises the respect towards partners and suppliers.

5.3.3.1 Grow leaders who understand the work and live the philosophy

Principle 9 consists of growing leaders inside the organisation who understand the work and to carry out the philosophy. By growing and training employees, this helps the company grow simultaneously as both people and the organisation grow together. The respondents were asked about statements such as if there are training programs in place within the company to grow leaders and if training is done, often for the employees of the company to grow their skills and method of doing procedures. Statistics from pillar 9 are shown in Figure 5.9. The graph shows that 20% strongly agrees with this pillar, 56% agrees, 20% responded with the neutral option and 4% responded with them disagreeing.

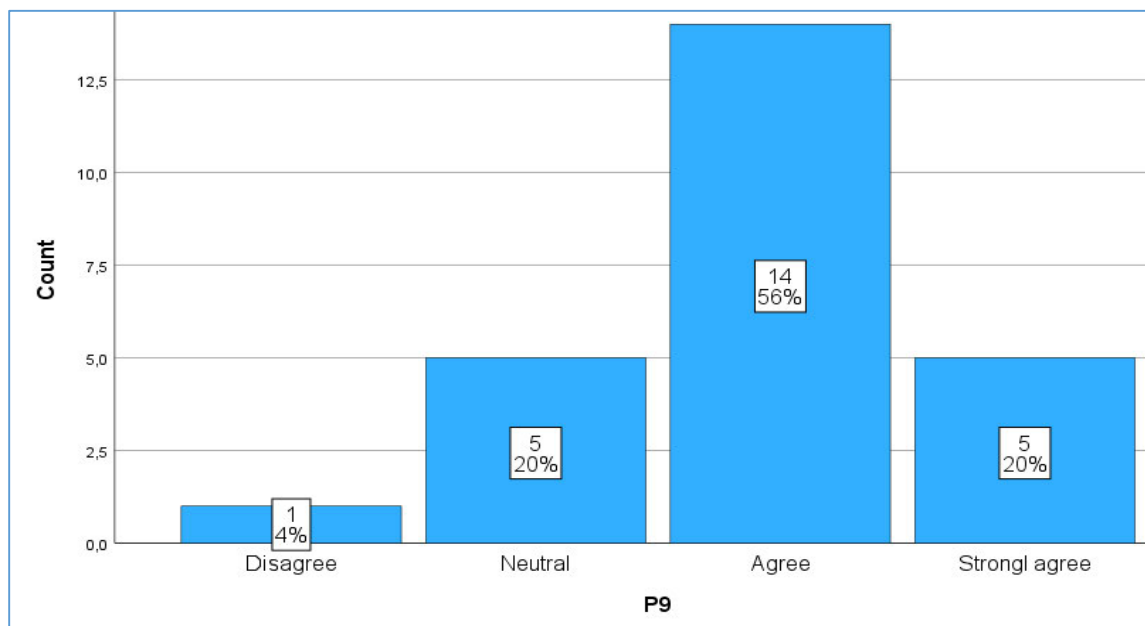


Figure 5.9 : Statistics for Principle 9

From the statistics of this principle, the mean statistic of 3.920; skewness is -0.483 while kurtosis is 0.44. The skewness value is negative, an indication that the distribution lies more to the right of the median, revealing that individuals strongly agree that there are training programs available at the company. The positive kurtosis value points out a steeper distribution. These descriptive values are shown in Table 5.11.

Table 5.11 : Statistics for principle 9 of the People and partners level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P9	3.920	4.000	0.759	-0.483	0.444

5.3.3.2 Developing exceptional people and teams

By developing people, an individual's performance is enhanced and this subsequently adds value whenever multifunctional teams are formed and grouped. In overall, this adds to the success of any project or task for a company's short- and long-term plan. Principle 10 is about developing exceptional people and teams within an organisation. This plays a role in the TPS model that as the model is implemented, individuals should be educated on successful implementation techniques.

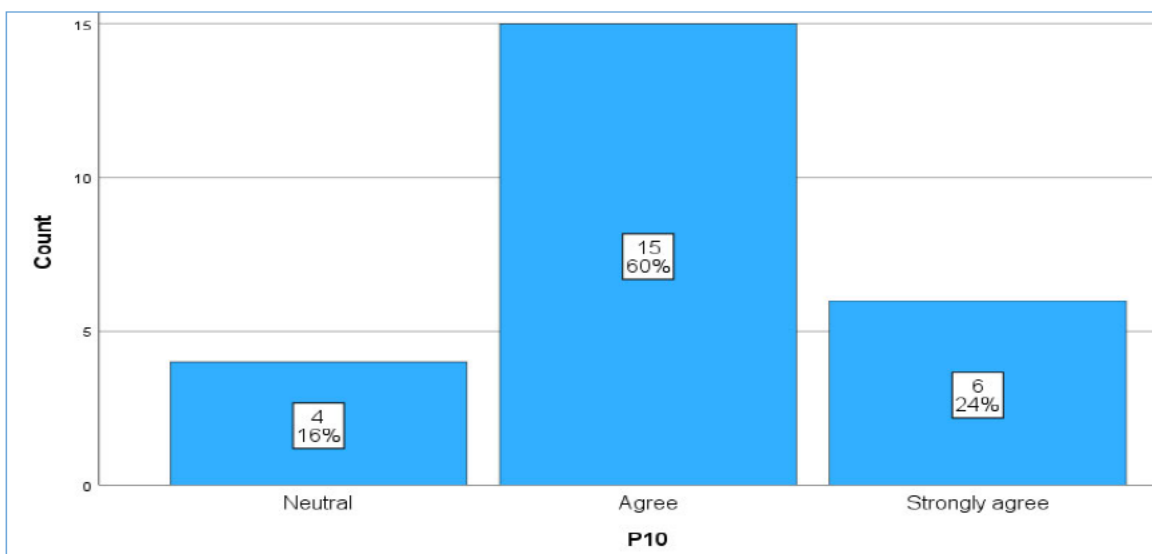


Figure 5.10 : Statistics for Principle 10

For this principle, respondents were asked if there are activities in the workplace that consist of cross functional teams. Individuals were also asked if they are developed to follow the company's philosophy. Figure 5.10 shows the results for this principle where 24% strongly agree, 60% agree and 16% responded neutral. As shown in Table 5.12, the statistics for this principle also shows a mean of 4.080; skewness of -0.065 and kurtosis of -0.313. The skewness is negative, an indication that the distribution lies more to the

right of the median indicating that majority of the respondents agreed with this statement. A negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

Table 5.12 : Statistics for principle 10 of the People and partner’s level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P10	4.080	4.000	0.640	-0.065	-0.313

5.3.3.3 Respect extended network of partners and suppliers

Principle 11 of the model consists of respecting, assisting and growing partners and suppliers of the company where TPS is implemented. By growing an organisation’s partners, that would enable them to have efficient processes with good quality products. For this principle, respondents were asked if the company assists in improving suppliers and partners. The statistics are shown below in Figure 11. From the statistics, 20% of the respondents strongly agreed, 56% of the respondents agreed, 20% of the respondents responded with neutral and 4% disagreed.

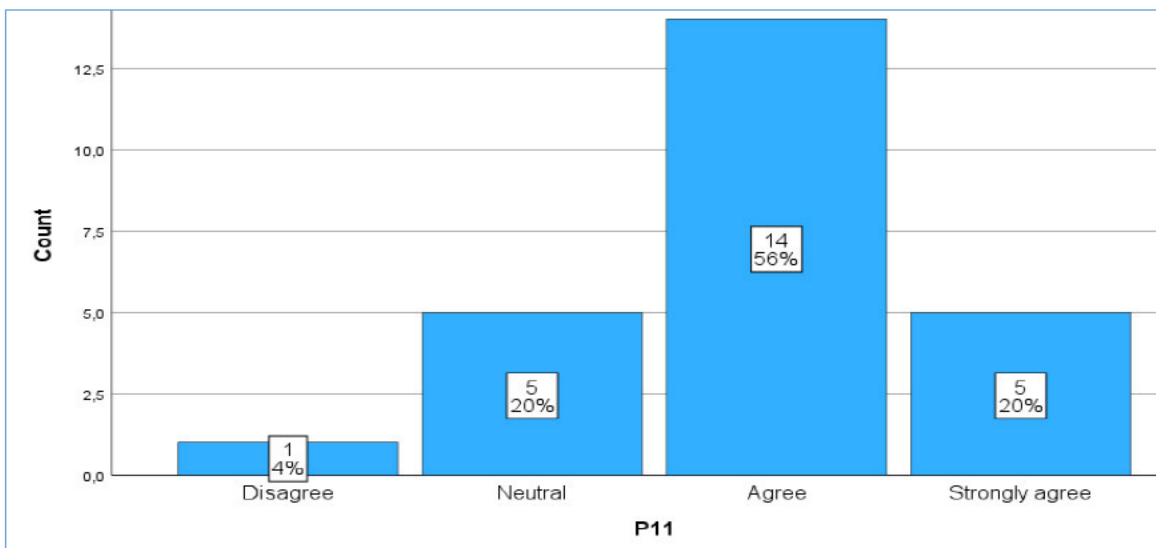


Figure 5.11 : Statistics for Principle 11

Table 5.13 also shows the statistics for principle 18. This principle has a mean statistic of 3.920; skewness of -0.483 and a kurtosis of 0.44. The skewness value is negative, an indication that the distribution lies more to the right of the median, revealing that the

respondents agreed that the company assists suppliers and partners that contributes to business.

Table 5.13 : Statistics for principle 11 of the People and partners level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P11	3.920	4.000	0.759	-0.483	0.444

5.3.4 Problem solving level

The 4th level of the TPS model consists of the last three principles, which is pillar 12, Genchi genbutsu; pillar 13, Decisions by slow consensus, implement decisions quickly and pillar 14, kaizen and becoming a learning organisation. Each of these pillars and the statistics are explained further below.

5.3.4.1 Genchi Genbutsu – Go see for yourself

Genchi Genbutsu is a Japanese term which means go see for yourself. It also refers to going to the source or the problem or itself to fully understand the events that occurred. For this principle, respondents were asked if the term genchi genbutsu was familiar in and around the company. The statistic of this principle is shown below in Figure 5.12. For this principle, 64% of the respondents strongly agreed, while 32% of the respondents agreed and 4% were neutral in their responses.

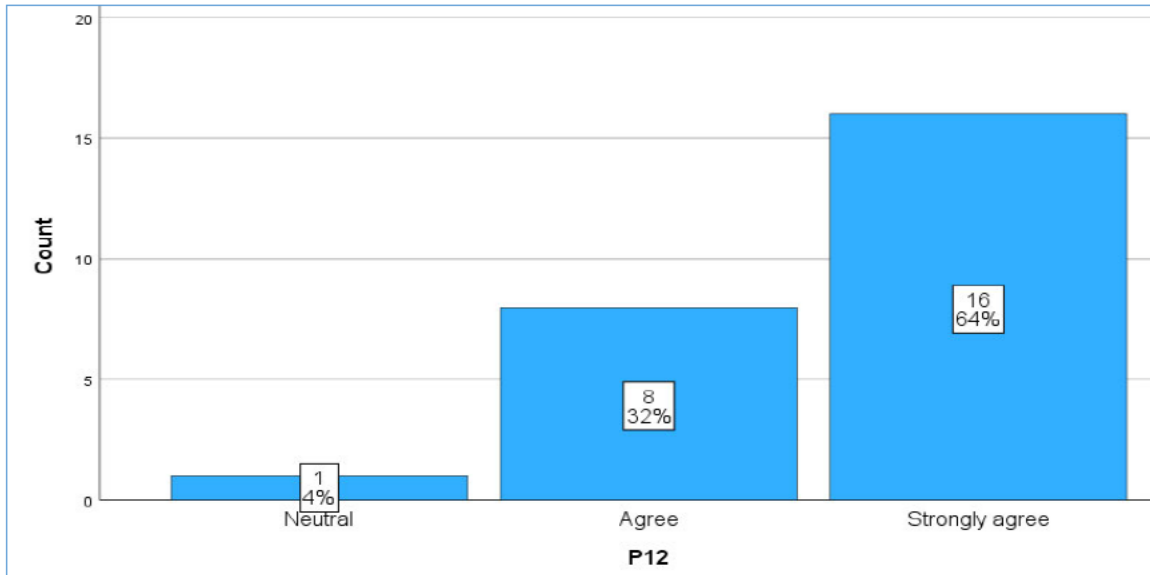


Figure 5.12 : Statistics for Principle 12

The mean statistic for principle 12 is 4.60; skewness -1.130 while the kurtosis of 0.439. This is shown below in Table 5.14. The skewness value is negative, an indication that the distribution lies more to the right of the median revealing that the term is familiar in and around the company.

Table 5.14 : Statistics for principle 12 of the Problem-solving level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P12	4.600	5.000	0.577	-1.130	0.439

5.3.4.2 Decisions by slow consensus: implement decisions quickly

Principle 13 explains the benefits of decisions by slow consensus. When decisions are made, it should be, carried out quickly and precisely with a plan with a passion and sense of mission. Decisions made should consists of opinions from all departments and a formed decision should be carried out with a plan. For this principle respondents were asked if decisions were made after carefully considering all options and if the decisions that were made were implemented rapidly. The answers from the respondents are shown graphically in Figure 5.13.

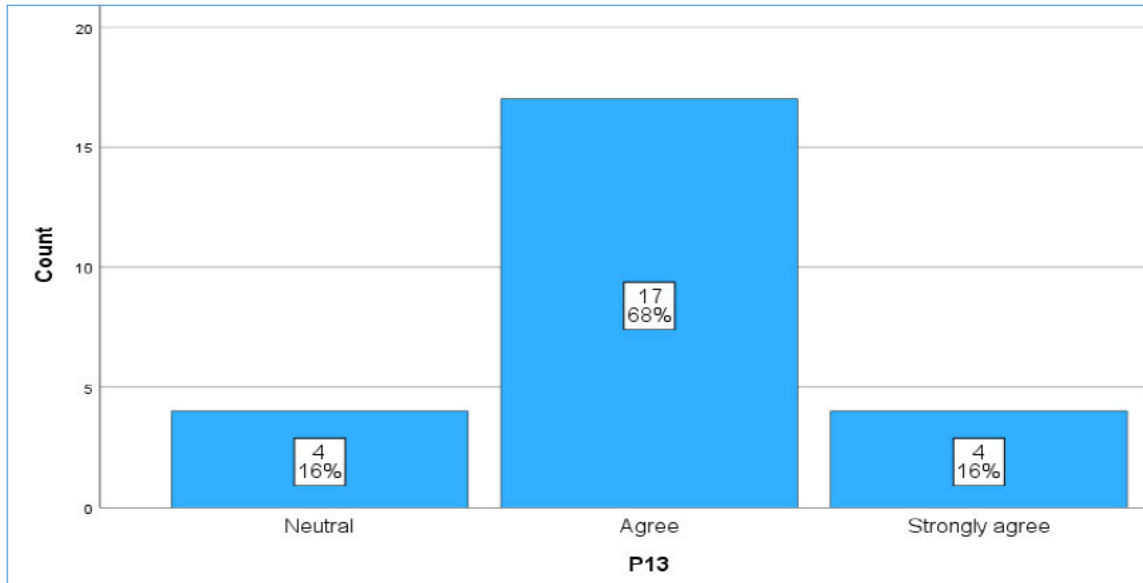


Figure 5.13 : Statistics for Principle 13

For this principle, 16% of the respondents responded with strongly agree, 68% agree and 16% were neutral. The statistics of principle 13 has a mean of 4.0; skewness of 0.20 and a kurtosis of 0.439. The skewness has a positive value which indicates kurtosis being a positive value indicates a slightly steeper distribution. The skewness is positive, an indication that the distribution lies more to the left of the median indicating that individuals agreed with the statements. This is shown below in Table 5.15.

Table 5.15 : Statistics for principle 13 of the problem-solving level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P13	4.000	4.000	0.577	0.200	0.439

5.3.4.3 Kaizen, become a learning organisation

Principle 14, which is the last principle of the last level is about kaizen and becoming a learning organisation. Through kaizen and continuously improving, we can improve processes and eliminate costs where applicable. With this principle, respondents were asked if the tier-one company is a learning organisation and as reflection if continuous improvement is carried out. The result from this principle is shown below in figure 5.14 where 36% responded by strongly agreeing, 52% agreed and 12% responded with neutral.

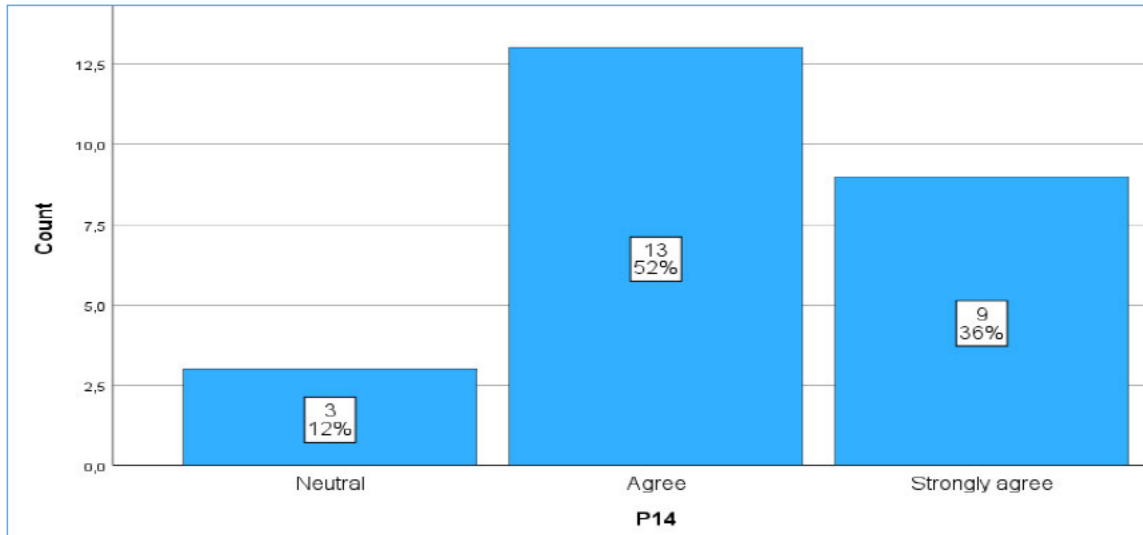


Figure 5.14 : Statistics for Principle 14

The statistics from principle 14 is shown in Table 5.16 a mean of 4.240; skewness of -0.302 and kurtosis of -0.612 were calculated. The negative kurtosis value points out that the distribution has a lighter tail than the normal distribution indicating that individuals agreed with this statement.

Table 5.16 : Statistics for principle 14 of the problem-solving level

	Mean	Median	Std. Deviation	Skewness	Kurtosis
P14	4.240	4.000	0.663	-0.302	-0.612

5.4 Quantitative Results for the Pyramid model for the tier-two supplier

Results from the tier-two supplier are shown below for each level and each principle. Much of the data varies from company to company, this is shown graphically.

5.4.1 Philosophy level

The participants were asked to express their perception around the statement “Toyota Production System (TPS) can improve profitability, process and quality in a business”. From the statistics shown in Figure 5.15, it was noted that 68% of the respondents agreed with the statement, while 20% of the respondents strongly agreed and 12% of the individuals were neutral in their answers.

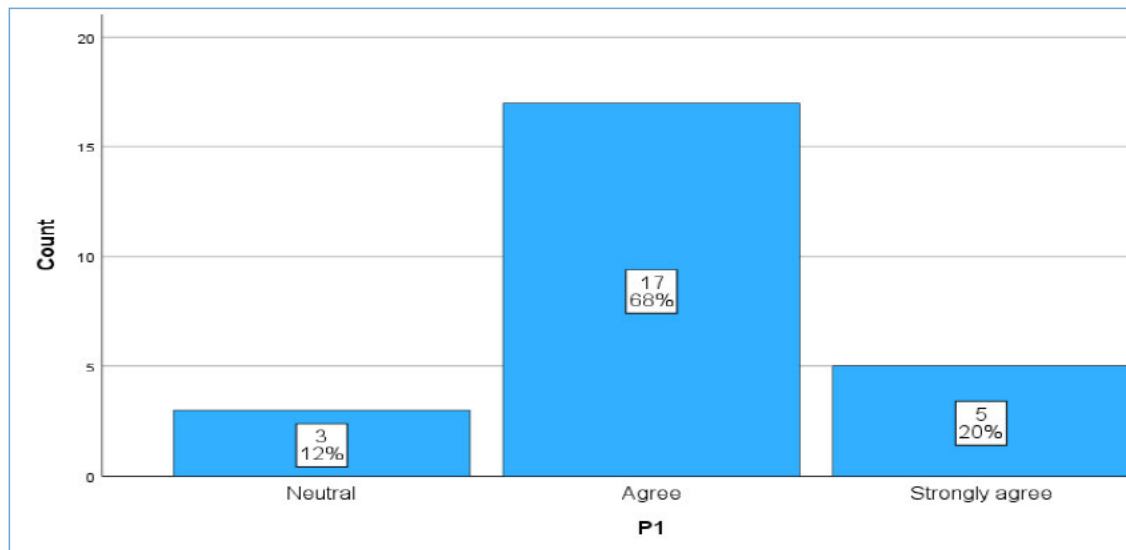


Figure 5.15: Statistics for Principle 1

Table 5.17 shows the descriptive statistics of the data. From the data below, we can see principle 1 has the mean statistic of 4.08; skewness is 0.026 while kurtosis is 0.429. The skewness value is a positive value, an indication that the distribution lies more to the left of the median, revealing that the participants agree with the statement while some were neutral.

Table 5.17: Statistics for principle 1 of the philosophy level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P1	25	4.08	0.572	0.026	0.429

5.4.2 Process level

5.4.2.1 One-piece flow (waste elimination)

Respondents were asked to express their perceptions on the one-piece flow principle. The statistics shown graphically in Figure 5.16 show that 52% agreed that their company has a continuous improvement culture and continuously improves their process, whereas 40% strongly agreed and 8% were neutral. Table 5.18 shows the statistics of the data. This principle displays a mean statistic of 3.64; skewness is -0.150 while the kurtosis is 0.108 indicating that majority of the respondents agreed with the statements.

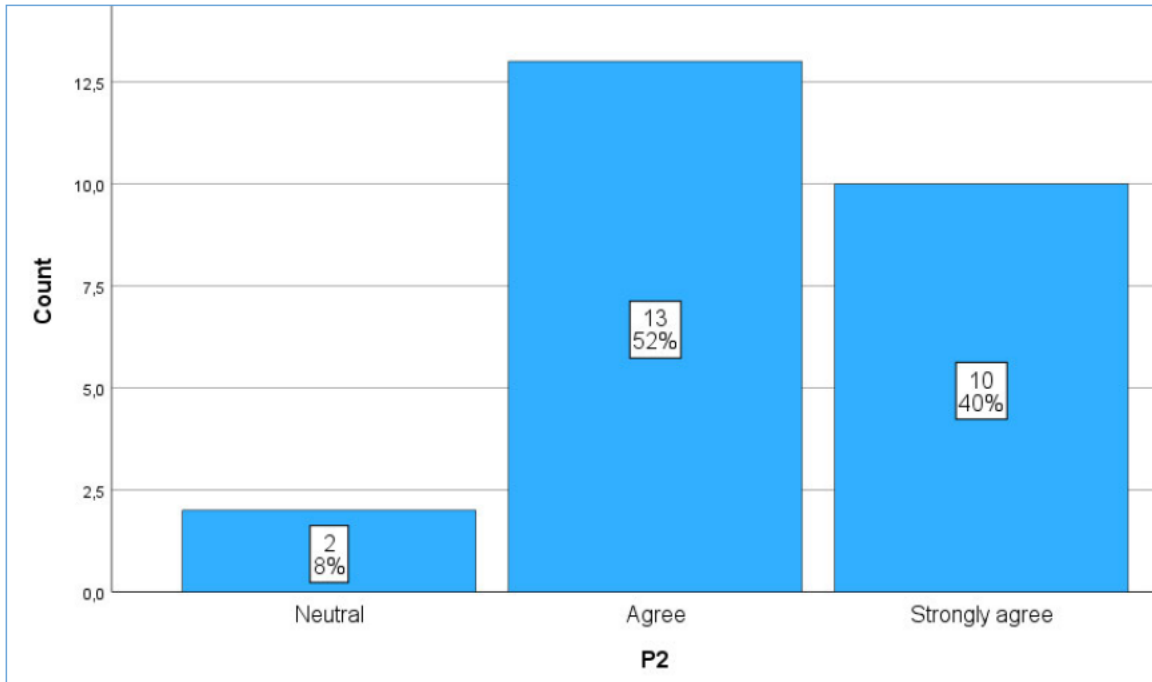


Figure 5.16 : Statistics for Principle 2

Table 5.18 : Statistics for principle 2 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P2	25	3.64	0.700	-0.150	0.108

5.4.2.2 Use pull system to avoid over production

Respondents were asked to express their perceptions on the pull system which is principle 3 of level 2. The respondents were also asked if their company uses a pull system to avoid overproduction as well as if this methodology, the pull system works for the company or not. The statistics shown graphically in Figure 5.17 show that 56% agreed and 12% strongly agreed whereas 32% were neutral on this principle. Table 5.19 shows you the statistics of the data. This item displays a mean statistic of 3.80; skewness of 0.202 while the kurtosis is - 0.480. The skewness value is positive, an indication that the distribution lies more to the left of the median. This reveals that there is much improvement required in this principle. A negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

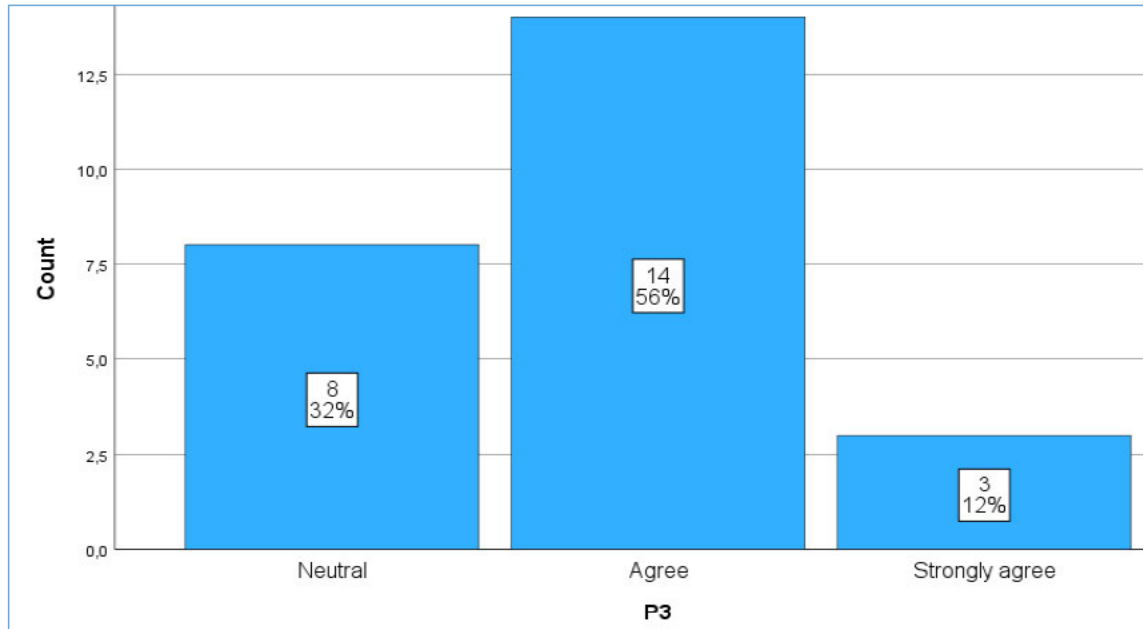


Figure 5.17 : Statistics for Principle 3

Table 5.19 : Statistics for principle 3 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P3	25	3.80	0.645	0.202	-0.480

5.4.2.3 Heijunka

Respondents were asked to express their perceptions on Heijunka, is principle 4. The respondents were also asked if their company makes it known of the 7 types of waste as well as if there are any ongoing activities in the workplace. The statistics show that 36% agreed; 20% strongly agreed whereas 32% were neutral on this principle and 12% responded by disagreeing. This is shown graphically in Figure 5.18.

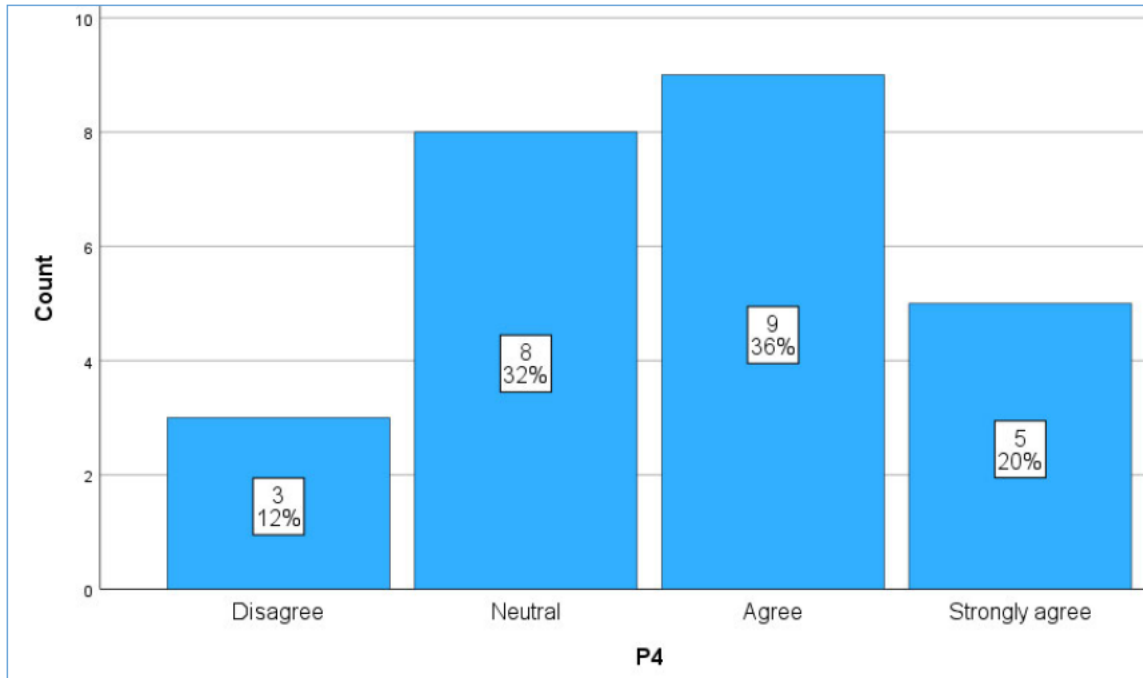


Figure 5.18 : Statistics for Principle 4

Table 5.20 below shows you the statistics of the data. This item displays an item mean statistic of 3.64; skewness of -0.122 while the kurtosis is -0.791. The skewness value is negative, an indication that the distribution lies more to the right of the median, revealing that the tier-two company does not share much knowledge on the 7 types of wastes.

Table 5.20 : Statistics for principle 4 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P4	25	3.64	0.952	-0.122	-0.791

5.4.2.4 Jidoka – Build in quality

Respondents were asked to express their perceptions on Jidoka, a concept also known for building quality into a process. This is principle 5 from the process level. The respondents were asked to express their perception concerning this principle and if quality is at its best and delivered to the customer first time around. The other statement which was asked is that if there are alert systems in the manufacturing process to identify defects at the same time. The statistics show that 52% agreed and 16% strongly agreed

whereas 7% were neutral on this principle and 4% responded with disagree. This is shown graphically in Figure 5.19. Table 5.21 below shows you the statistics of the data collected. This item displays an item mean statistic of 3.80; skewness is -0.244 while the kurtosis is -0.005 indicating that majority of the students agreed with these statements of the principle. The negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

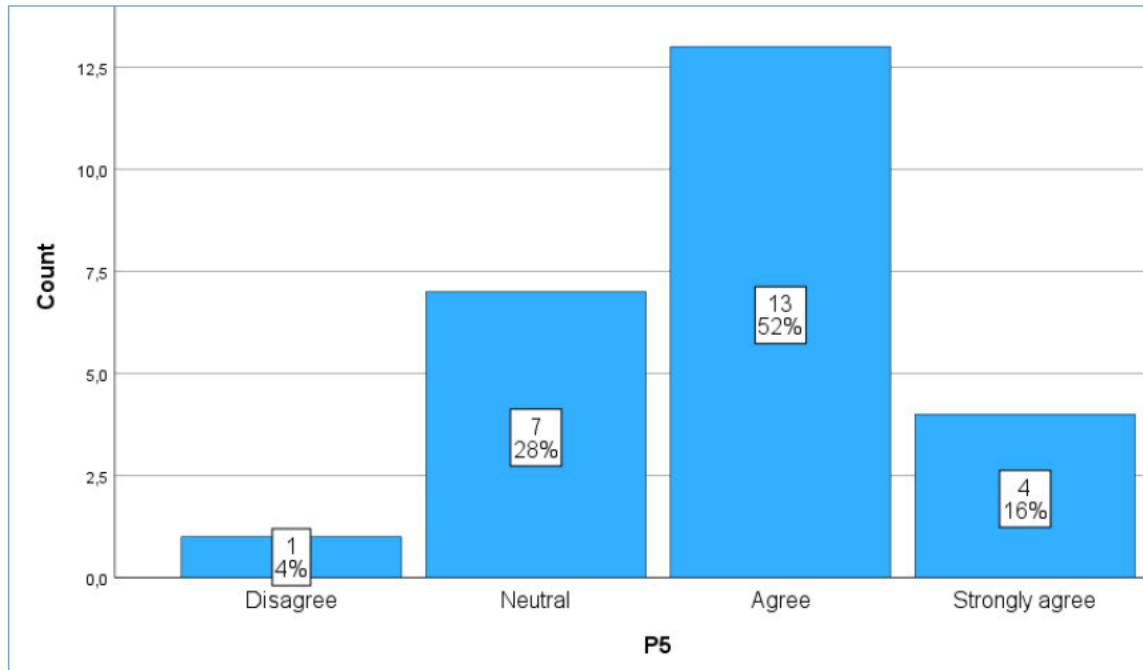


Figure 5.19 : Statistics for Principle 5

Table 5.21 : Statistics for principle 5 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P5	25	3.80	0.764	-0.244	-0.005

5.4.2.5 Standardised work

For this pillar, respondents were asked if standardised work is part of their daily routine at their workplace. The other statement that was asked was if respondents had measures in place for standardised work. From the respondents and their answers, the statistics show that 8% strongly agree, 68% agree and 24% were neutral in their answers. This is shown graphically below in Figure 5.20. The statistics for principle 6 display a mean statistic of 3.84; skewness of -0.097 while the kurtosis being 0.352. A positive kurtosis value points out a slightly steeper distribution indicating that majority of the respondents agreed with the statements for this principle. With the skewness value being positive, an indication that the distribution lies more to the left of the median. This is also shown below in Table 5.22.

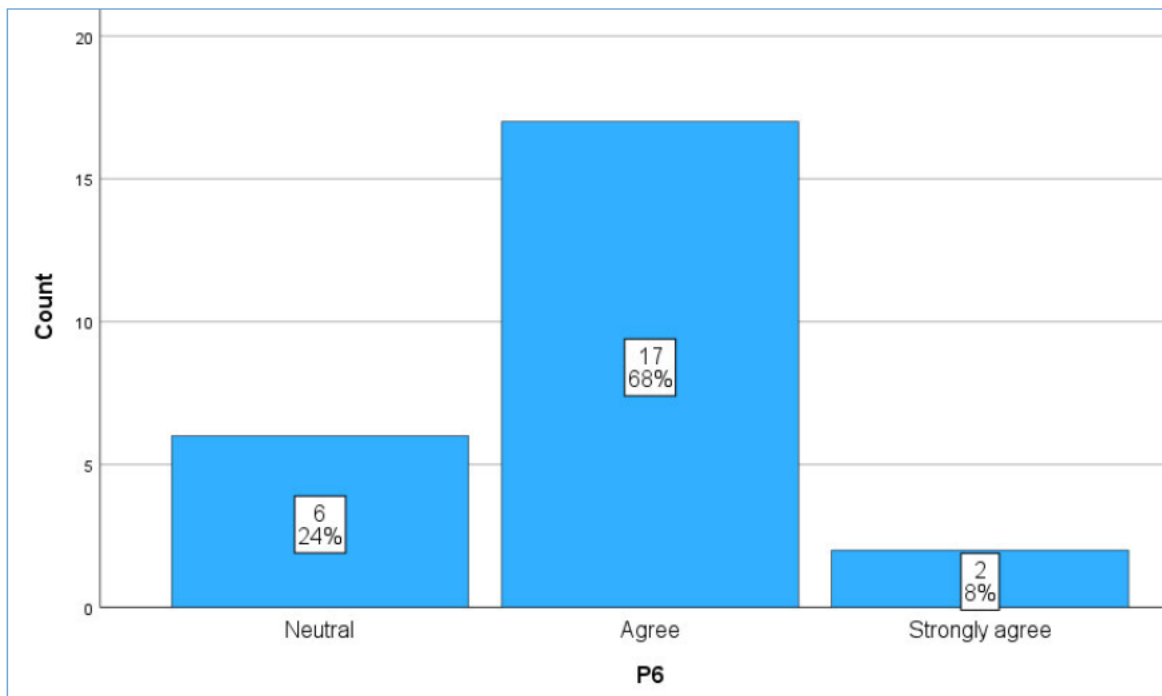


Figure 5.20 : Statistics for Principle 6

Table 5.22 : Statistics for principle 6 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P6	25	3.84	0.554	-0.097	0.352

5.4.2.6 Visual management

For this pillar, the respondents were asked if there were visual controls at the process to prevent deviation from the process. 12% of the respondents strongly agreed with this stating that there are visual items at the process, 68% agreed, 16% of the respondents responded neutral and 4% disagreed. This is shown in Figure 5.21.

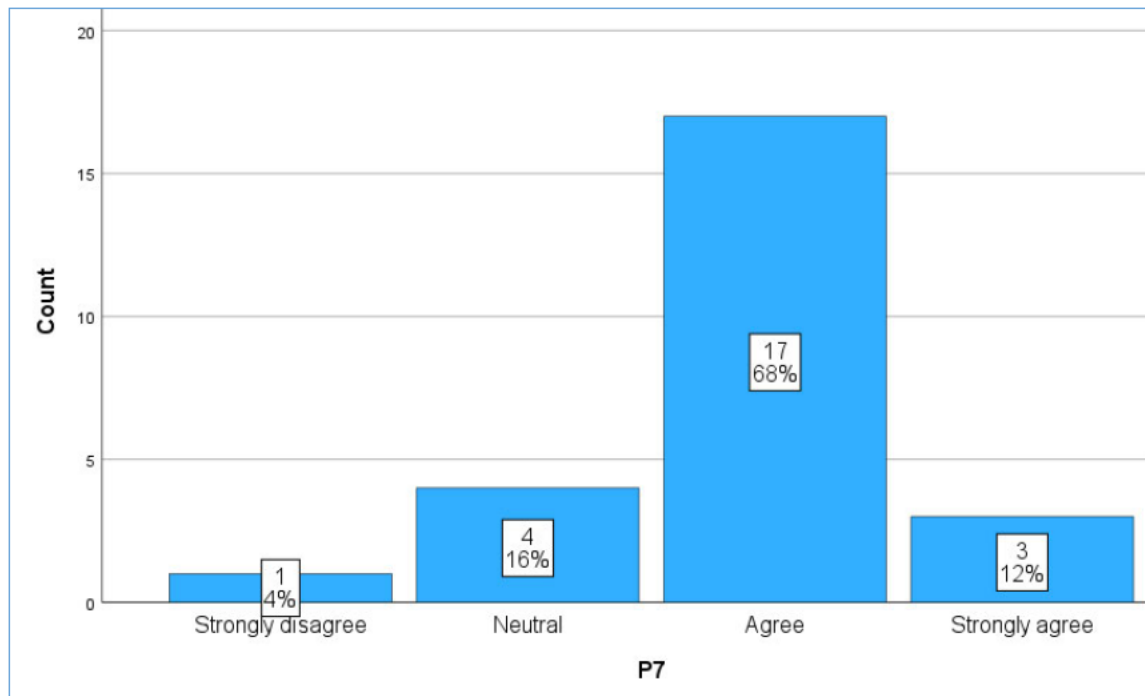


Figure 5.21 : Statistics for Principle 7

These statistics show that of a mean of 3.84; skewness is -1.816 and a kurtosis of 6.057. The skewness value is negative, an indication that the distribution lies more to the right of the median while the kurtosis being a positive value indicates a slightly steeper distribution. This indicated that majority of the respondents reacted by agreeing as there are visual aids at the processes. These values are shown in Table 5.23.

Table 5.23 : Statistics for principle 7 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P7	25	3.84	0.800	-1.816	6.057

5.4.2.6 Use reliable and proven technology

The respondents from the tier-two company were asked if their company had cutting edge technology to improve their processes. They were also asked if their company is currently investigating any further technology to improve their business processes. The statistic from this pillar is shown in Figure 5.22, 4% responded with strongly agree, 40% agree with this statement, 20% responded neutral; 20% disagreed and 16% strongly agreed.

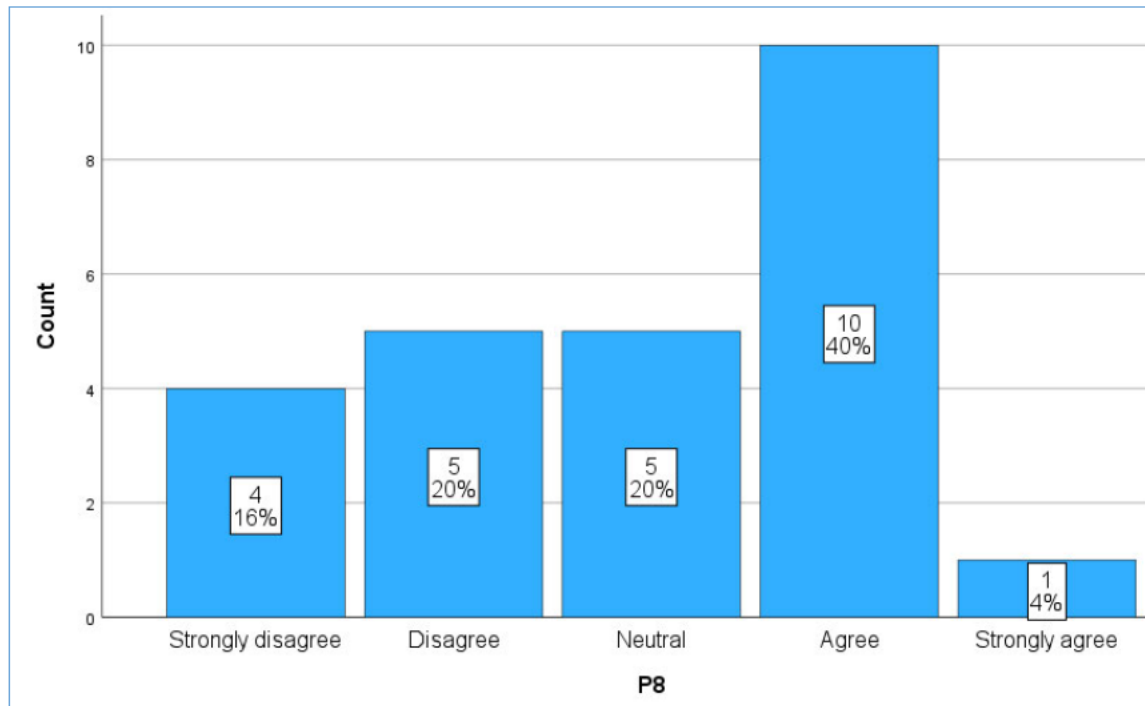


Figure 5.22 : Statistics for Principle 8

The statistics for this pillar as also shown below in Table 5.24. This table displays a mean of 2.96; skewness of -0.381 and a kurtosis of -1.087. A negative kurtosis value points out that the distribution has a lighter tail than the normal distribution. A negative skewness value also indicates that the distribution lies more to the right of the median, revealing that the tier-two company is in fact not investigating any technology to advance their processes.

Table 5.24 : Statistics for principle 8 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P8	25	2.96	1.207	-0.381	-1.087

5.4.3 People and partner level

5.4.3.1 Growing leaders who understand the work and live the philosophy

For this principle, respondents were asked about statements such as if there are training programs in place within the company to grow leaders and if training is done often for the employees of the company to grow their skills and method of doing procedures. Statistics from pillar 9 are shown in Figure 5.23. The graph shows that 12% strongly agree, 32% agree, 32% responded with neutral with this pillar, while 12% responded with the disagree option and 12% responded with them strongly disagreeing.

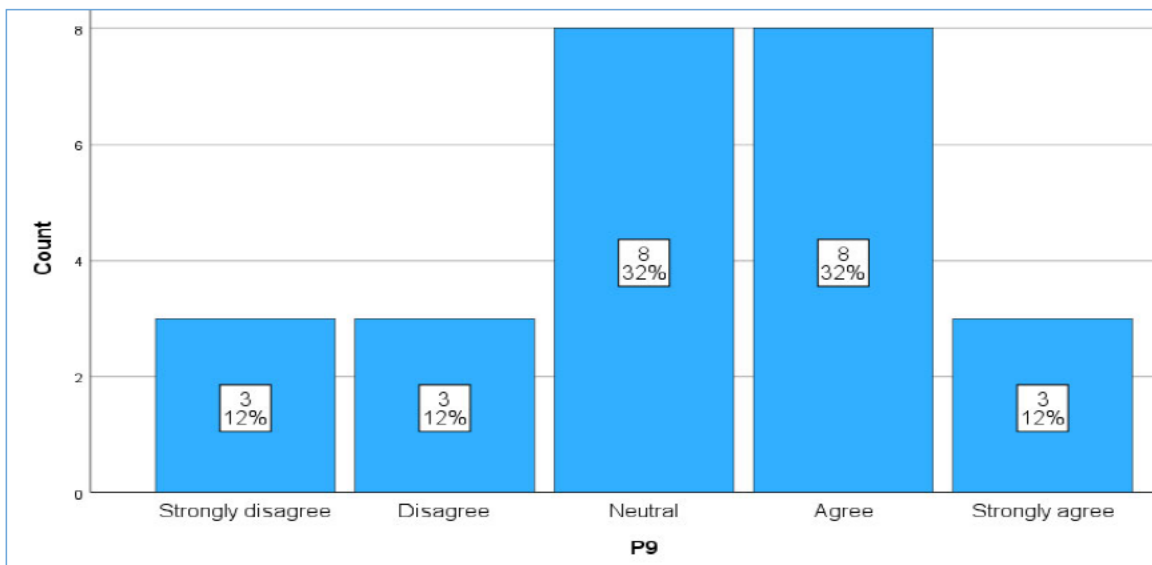


Figure 5.23 : Statistics for Principle 9

From the statistics of this principle, the mean statistic of 3.20; skewness is -0.419 while kurtosis is -0.4447. These statistics is shown below in Table 5.25. The skewness value is negative, an indication that the distribution lies more to the right of the median, revealing that there are somewhat training programs available while others did not agree that this is available. The negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

Table 5.25 : Statistics for principle 9 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P9	25	3.20	1.190	-0.419	-0.447

5.4.3.2 Developing exceptional people and teams

There are many benefits for developing people and teams. By expanding knowledge, you expand the area for growth and for new innovative ideas to be researched and implemented. For this principle, respondents were asked if there are activities in the workplace that consist of cross functional teams. Individuals were also asked if they are developed to follow the company's philosophy. Figure 5.24 shows the results for this principle where 8% strongly agree, 52% agree while 24% responded neutral and 16% responded with disagree.

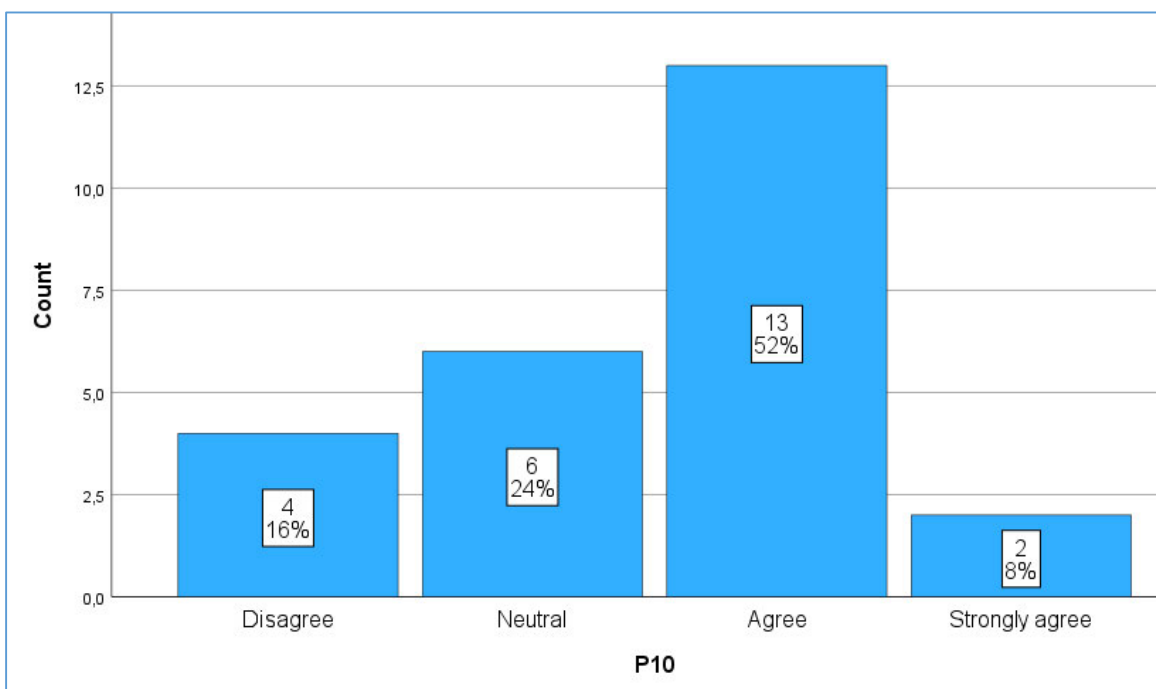


Figure 5.24 : Statistics for Principle 10

The statistics for this principle shown in Table 5.26 indicate a mean of 3.52; skewness of - 0.476 and kurtosis of - 0.443. The skewness is negative, an indication that the distribution lies more to the right of the median. This indicates that even though some respondents reacted by disagreeing and by being neutral, majority of the respondents agreed with the statement. A negative kurtosis value points out that the distribution has a lighter tail than the normal distribution.

Table 5.26 : Statistics for principle 10 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P10	25	3.52	0.872	-0.476	-0.443

5.4.3.3 Respect extended network of partners and suppliers

For this principle, respondents were asked if the company assists in improving suppliers and partners. The statistics are shown in Figure 5.25. From the statistics, 4% of the respondents strongly agreed, 36% of the respondents agreed, 16% of the respondents responded with neutral, 36% disagreed and 8% responded by strongly disagreeing.

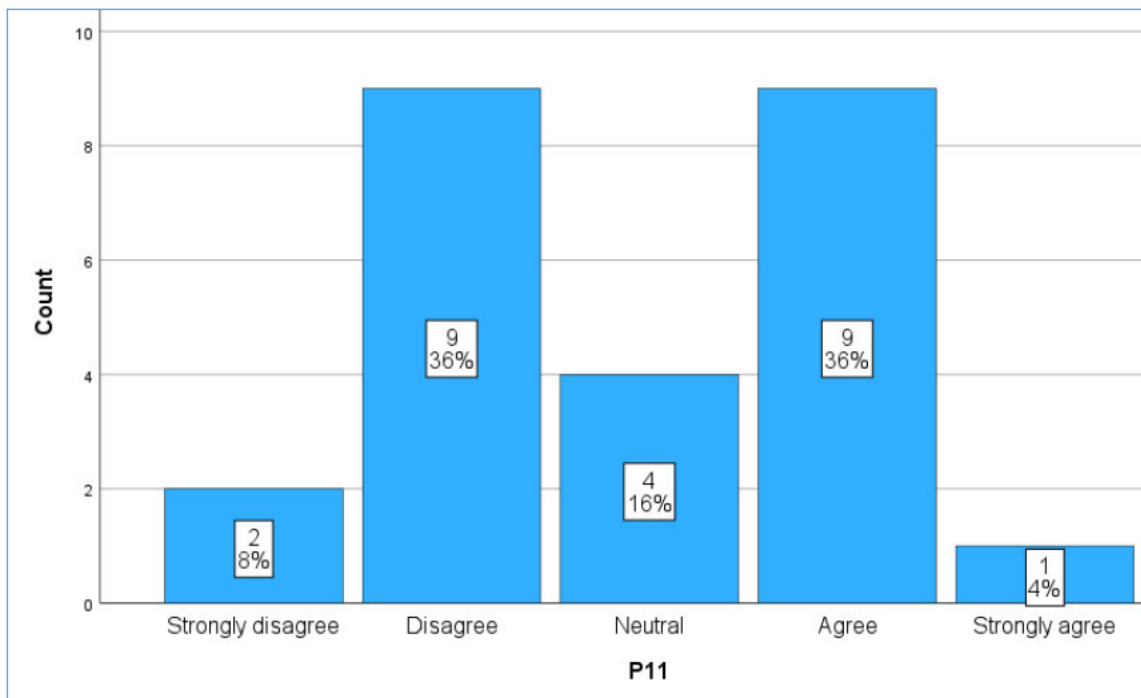


Figure 5.25 : Statistics for Principle 11

Table 5.27 also shows the statistics for principle 11. This principle has a mean statistic of 2.92; skewness of -0.027 and a kurtosis of -1.179. The skewness value is negative, an indication that the distribution lies more to the right of the median, revealing that the respondents agreed that the company assists suppliers and partners that contributes to business.

Table 5.27 : Statistics for principle 11 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P11	25	2.92	1.115	-0.027	-1.179

5.4.4 Problem solving level

5.4.4.1 Genchi Genbutsu – Go see for yourself

For this principle, respondents were asked if the term genchi genbutsu was familiar in and around the company. This term is basically described as going to the source of the problem. The statistic of this principle is shown below in Figure 5.26. For this principle, 8% of the respondents strongly agreed, while 24% of the respondents agreed, 32% were neutral in their responses while 8% and 28% disagreed and strongly disagreed respectively.

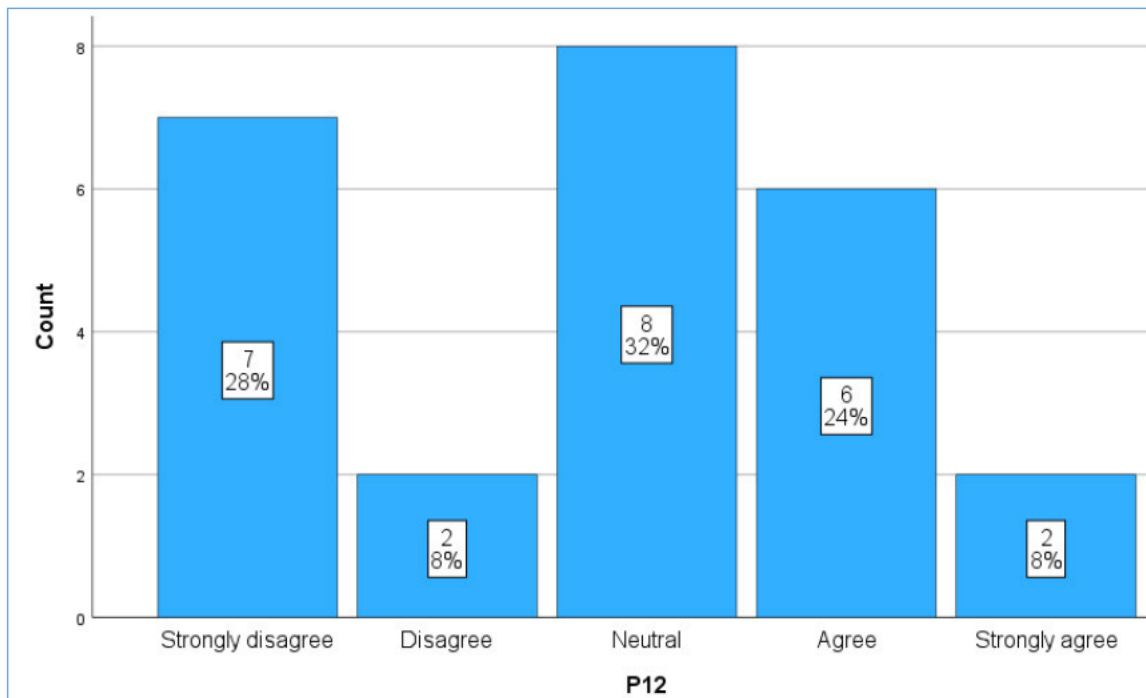


Figure 5.26 : Statistics for Principle 12

The mean statistic for principle 12 is 2.76; skewness -0.096 while the kurtosis of -1.162. This is shown below in Table 5.28. The skewness value is negative, an indication that

the distribution lies more to the right of the median revealing that Genchi Genbutsu is not always followed out at the tier-two supplier.

Table 5.28 : Statistics for principle 12 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P12	25	2.76	1.332	-0.096	-1.162

5.4.4.2 Decisions by slow consensus: implement decisions quickly

For this principle respondents were asked if decisions were made after carefully considering all options and if the decisions that were made were implemented rapidly. The answers from the respondents are shown graphically in Figure 5.27. For this principle, 12% of the respondents responded with strongly agreeing; 32% responded by agreeing; 36%, neutral; while 16% and 4% responded by disagreeing and strongly disagreeing respectively.

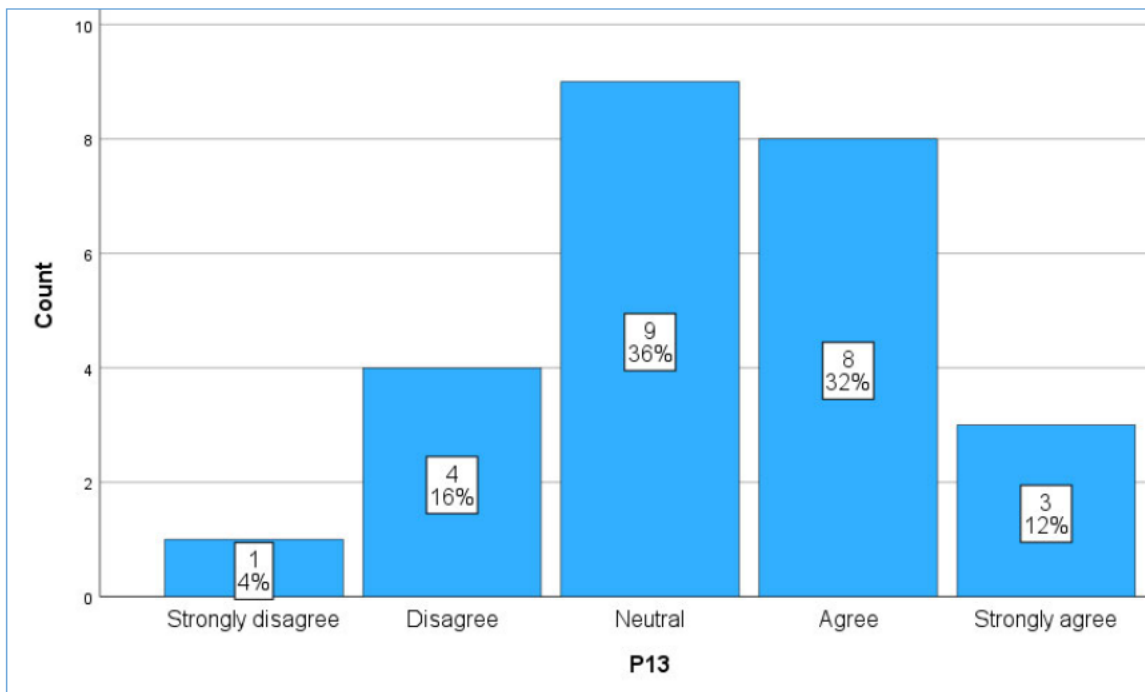


Figure 5.27 : Statistics for Principle 13

The statistics of principle 13 shown below in Table 5.29 has a mean of 3.32; skewness of -0.218 and a kurtosis of -0.232. The skewness value is negative, an indication that the

distribution lies more to the right of the median, revealing that the respondents were in agreement for this principle.

Table 5.29 : Statistics for principle 13 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P13	25	3.32	1.030	-0.218	-0.232

5.4.4.3 Kaizen, become a learning organisation

Principle 14, which is the last principle of the last level is about kaizen and becoming a learning organisation. As much as this is the last step, all companies should apply kaizen to their processes and continuously improve to meet market demands and be the leading competitor. With this principle, respondents were asked if the tier-two company is a learning organisation and as reflection, if continuous improvement is carried out. The result from this principle is shown below in Figure 5.28 where 8% responded by strongly agreeing, 56% agreeing; 20% neutral and 12% and 4% responded by disagreeing and strongly disagreeing.

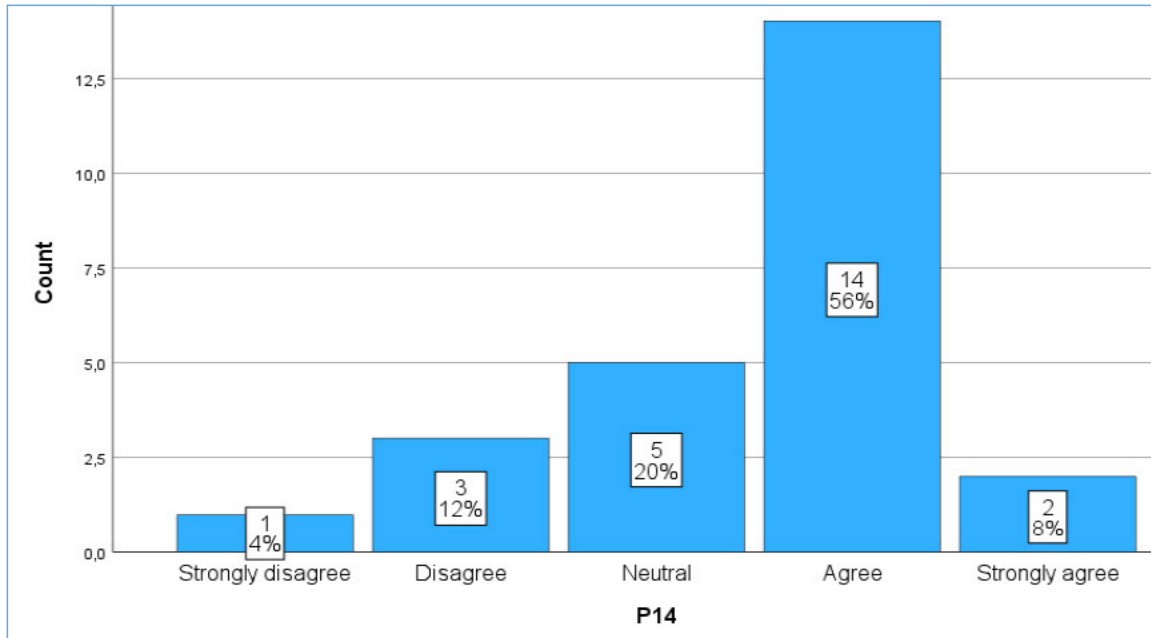


Figure 5.28 : Statistics for Principle 14

The statistics of principle 14 shown below in Table 5.30 has a mean of 3.52; skewness of - 0.975 and a kurtosis of - 0.764. The skewness value is negative, an indication that the distribution lies more to the right of the median, revealing that the respondents were in favour or agreed to kaizen events in the organisation.

Table 5.30 : Statistics for principle 14 of the process level

	N	Mean	Std. Deviation	Skewness	Kurtosis
P14	25	3.52	0.963	-0.975	0.764

5.5 Comparative analysis of mean statistics for tier-one and tier-two supplier

The means from both suppliers are shown below in Table 5.31 and shown graphically in Figure 5.29. From the line graph we can see that the mean values the mean values for the tier-one supplier is higher for all principles as compared to the tier-two supplier. From this we can also see that the smallest difference between the mean values is for principle 7, visual management. This explains that both suppliers have visual aids such as work instructions and quality standards at their production processes. The biggest difference between the mean values between the tier-one and tier-two were for principle 12, Genchi

Genbutsu. This reveals that the tier-one supplier is more aware of the term as compared to the respondents from the tier-two supplier.

This highest mean value for the tier-one company was for principle 1; a mean value of 4.60. This indicates that for the philosophy level, respondents all strongly agreed or agreed on this pillar. This mean all respondents were aligned to the knowledge of Toyota model. This shows that the philosophy level was stronger and so was principle 1 as this level only consists of one principle. The smallest mean value for the tier-one company was for Principle 8; the use reliable and proven technology which is part of the process level of the Toyota Model. This informs us that the company still needs to improve on using and developing technology at their processes making it the weaker principle for the model.

For the tier-two supplier, the highest mean value being 4.08, this tells us that the respondents of the tier-two supplier are also very familiar and aware of the philosophy level of the model and this being the stronger principle and level of the model. With a mean value of 2.76, this also tells us that the tier-two supplier does not carry out Principle 12; the principle of genchi genbutsu strong enough, making this and the problem-solving level the weaker principle and weaker level of the model.

From the comparative analysis, we can also determine the stronger principle in each supplier. From the line graph below we can comprehend that principle 1 and principle 12 are stronger in the tier-one supplier whereas in tier-two, we can comprehend that principle 1 and principle 7 are the stronger principles in the tier-two supplier.

Table 5.31 : Tabulated comparative analysis of mean values of each supplier

	Tier – one supplier	Tier-Two supplier
P1	4.72	4.08
P2	4.32	3.64
P3	4.48	3.8
P4	4.56	3.64
P5	4.48	3.8
P6	4.48	3.84
P7	4.2	3.84
P8	3.52	2.96
P9	3.92	3.2
P10	4.08	3.52
P11	3.92	2.92
P12	4.6	2.76
P13	4	3.32
P14	4.24	3.52

The descriptive mean values are shown graphically below in Figure 5.29.

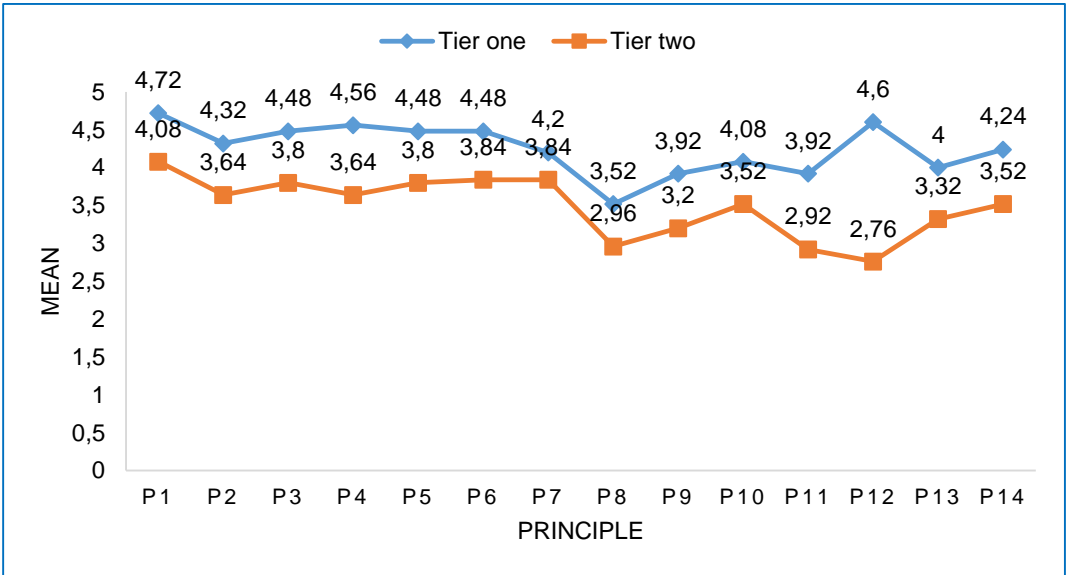


Figure 5.29 : Comparative analysis of mean values

As shown in Table 5.32, an independent samples t-test was conducted for the comparative analysis of mean statistics for tier-one and tier-two supplier since the population variance was unknown and the sample size per supplier was less than 30 each. The purpose of this test is to determine if the samples are different from each other. Tier 2 supplier was set as test variable while the tier-one supplier based was grouping variable.

Table 5.32: T Test values

Bayes Factor Independent Sample Test (Method = Roudner)						
	Mean Difference	Pooled Std. Error Difference	Bayes Factor	t	df	Sig.(2-tailed)
Tier-one	,4036	,15480	,328	2,607	12	,023
a. Assumes unequal variance between groups.						

The p-value tells you whether the mean difference is statistically significant or not. The p-value(0.023) is less the significance level of 0.05, therefore the null hypothesis was rejected and concluded that there is a significant difference between the implementation the Toyota production systems between the tier-one and the tier-two suppliers.

5.6 Continuous Improvement initiatives

The results from quantitative analysis of the pyramid model revealed that there is room for improvement on principle 2 and principle 7. This includes line balancing technique for process improvement in the assembly of automotive components and the implementation of an andon production management system to improve the efficiency of tracking of output scores.

5.6.1 Line balancing for one-piece flow improvement at tier-one supplier

5.6.1.1 Process flow for car seat assembly line

The tier-one supplier produces cover and seats for the new hybrid SUV automobile. At the final seat cover assembly line, it was found that the production line stopped on many occasions due to many reasons. Figure 5.30 shows the process flow from sewing cut pieces, which moved to the sewing assembly line. When a cover is fully sewn and

assembled during the sewing process, it is then transported to the seat assembly process. This is where the final seat set is assembled and then finally sent to the customer.

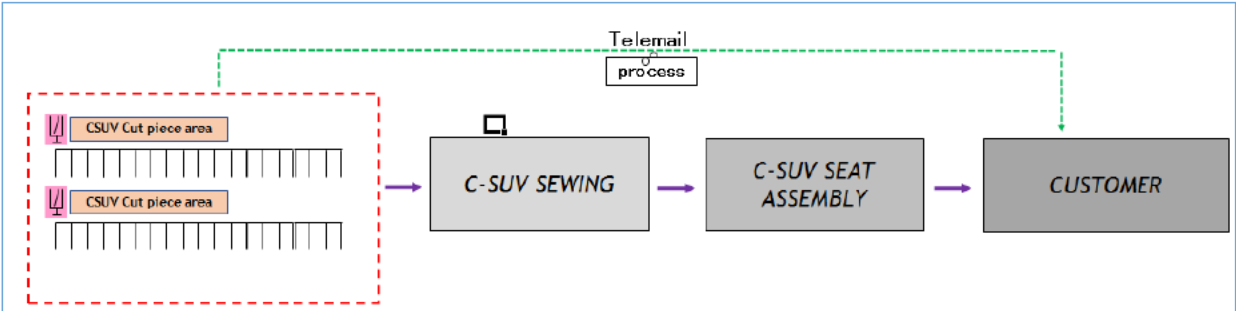


Figure 5.30: Material information flow showing process flow at a tier-one supplier

During the seat assembly process, each time there is a line stoppage, this is recorded on their daily production sheets. A work week production days' data was chosen and the information summarised of the factors leading to downtime is summarised in the pie chart below. The major contributor of the final production line belonged to the sewing assembly line, followed by external part issues and lastly quality issues.

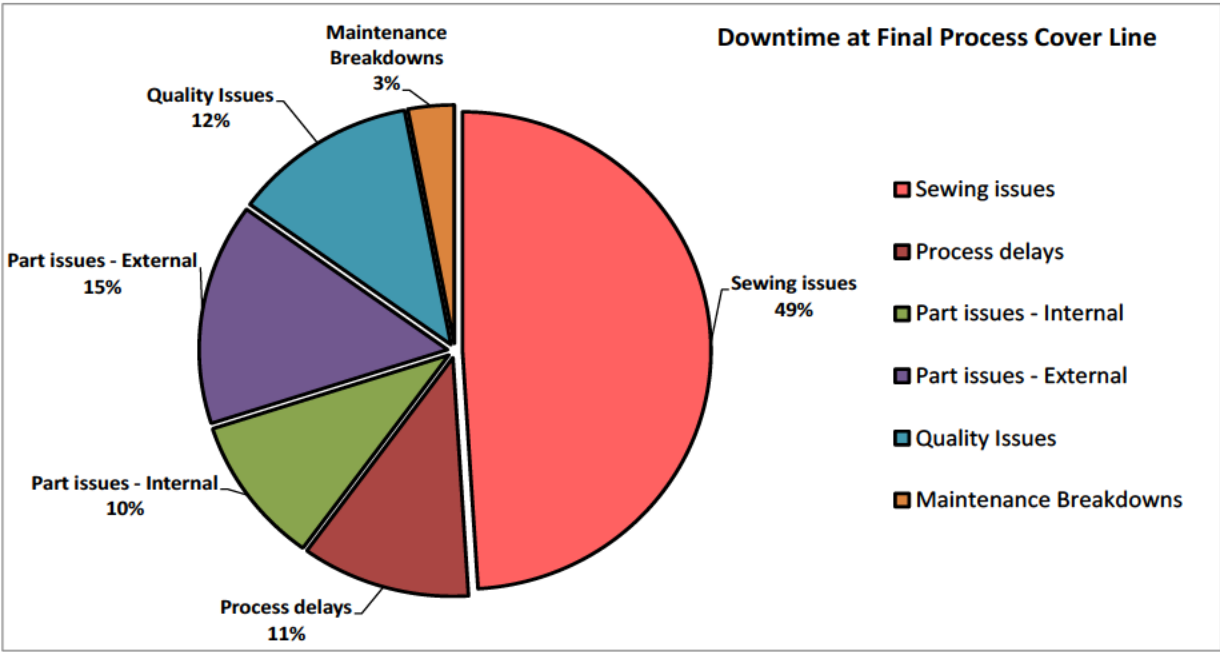


Figure 5.31: Pie chart showing downtime issues and major contributors

The overall front sewing line being investigated is made up of two interconnecting lines which are the front Sub line and the front main line as shown in Figure 5.32. In the sub line, which is the start of the assembly cover line, work units are pushed downstream after

each sub-component is finished at each station. Here, smaller handling and detailed working parts are sewn to avoid causing further delays on the mainline. These parts, when completed, are put back in dunnage's that are on rollers, moving to each station. Space is allocated for one or more work units in front of each station. This provides an available supply of work for each station. The front main-line is a continuous transport system (conveyor) that operates at a constant velocity. Here parts from the subline are placed on the conveyor for front main line operations to be completed. Once all components are assembled, finished goods (covers) are then sent to quality inspection for quality checks.

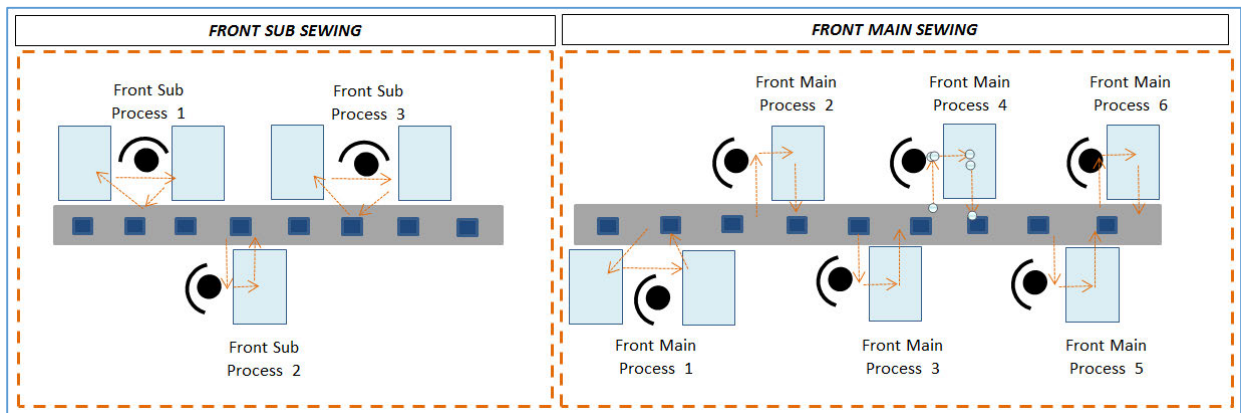


Figure 5.32: Front Sub Line and Front Main Line Sewing process flow

The process work sequence and elements for the Front Sub line and Front Main line are shown in Table 5.33 and Table 5.34.

Table 5.33: Elemental work for each process in Front Main Line

Process	Sequence	Elemental Work	Seconds
MAIN LINE	1	Sew Carpet to Cover Left Hand	581.6
		Sew Carpet to cover Right Hand	
		Sew Airbag Bolster Left Hand	
		Sew Airbag Bolster to Right Hand	
		Sew Non Airbag Bolster Right Hand	
		Sew Airbag Bolster Left Hand	
	2	Sew Suspender to Back Cover Left hand	437.2
		Sew Suspender to Back Cover Right hand	
		Sew Suspender to Cushion Cover Left hand	
		Sew Suspender to Cushion Cover Right hand	
	3	Sew Final carpet to cover Left Hand	457.8
		Sew Final carpet to cover Right Hand	
		Sew Zip to cover left hand	
		Sew Zip to cover Right hand	
	4	Sew patches to cover X 4 to Left hand - Back	424.8
		Sew Patches to cover X 4 to Right Hand - Back	
		Sew patches to cover X 4 to Left hand - Cushion	
		Sew Patches to cover X 4 to Right Hand - Cushion	
	5	Close Back pocket Left Hand	348.4
		Close Back pocket Right Hand	
		Close Cushion Cover Left Hand	
		Close Cushion Cover Right Hand	
	6	Sew plastic profiles to back cover Right Hand	320
		Sew plastic profiles to back cover Left Hand	
Sew plastic profiles to cushion cover Right Hand			
Sew plastic profiles to cushion cover Left Hand			

Table 5.34: Elemental work for each process in Front Sub Line

Process	Sequence	Elemental Work	Seconds
SUB LINE PROCESSES	1	Sew Airbag side shoulder piece Right Hand	524.6
		Sew Airbag side shoulder piece Left Hand	
		Sew Zip Left hand	
		Sew Zip Right Hand	
		Sew Patch to bolster Left Hand	
		Sew Patch to bolster Right Hand	
	2	Sew Leather to Foam Piece	352
		Sew Isofix tag Left Hand	
		Sew Isofix tag Right Hand	
		Sew Label Left Hand	
		Sew Label Right Hand	
		Sew Bolster Right Hand	
	3	Sew Bolster to inner facing Left Hand	582.6
		Sew Bolster to inner facing Right Hand	
		Top stitch Bolster Right Hand	
		Top Stitch Bolster Left Hand	
		Sew Upper and Lower facing Left Hand	
		Sew Upper and Lower facing Right Hand	

5.6.1.2 Potential causes for bottleneck processes

The Ishikawa diagram, also known as the Fishbone Diagram, assists staff in organisations to determine and understand the cause of a particular problem and to clarify issues. When the root because analysis was completed, it was found that there were many underlying factors that led to the process being unable to meet their targets. The Fishbone or Ishikawa diagram in Figure 5.33 shows factors that affected the process of not meeting the score.

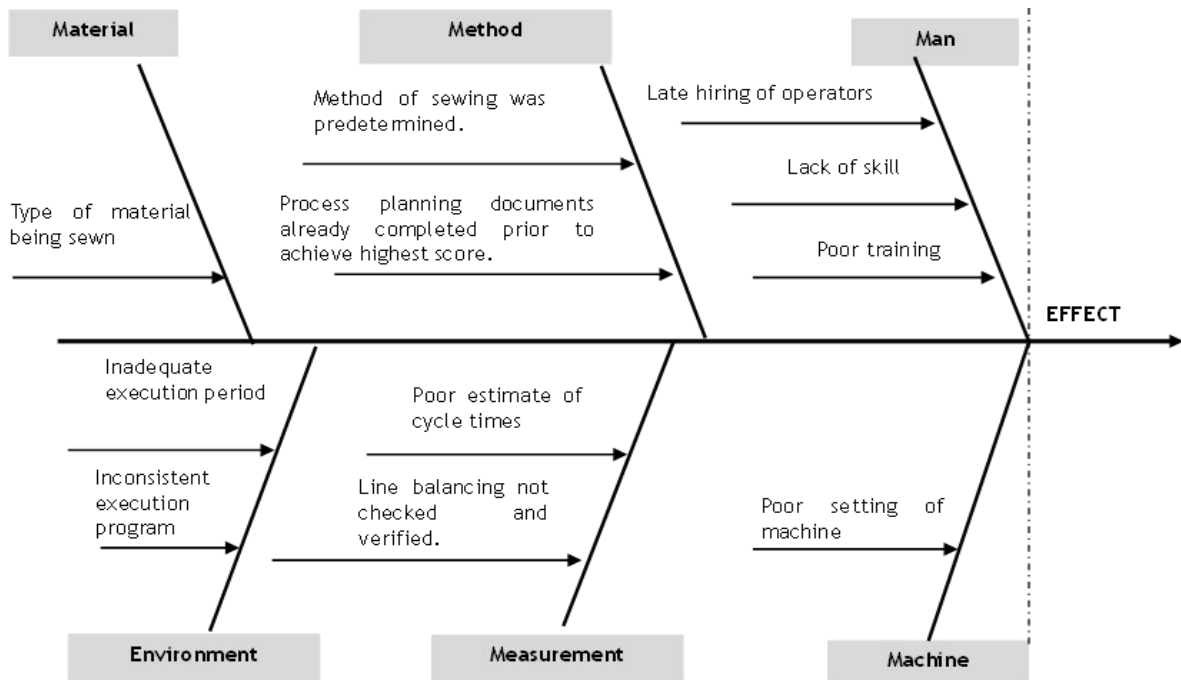


Figure 5.33: Ishikawa diagram for the bottleneck process

The total cycle time given to assemble the entire cover component was 2394 seconds for the front main line sewing and 1197 seconds for the Sub Line sewing. With this information, the number of machinery ordered and the headcount required to run this process were calculated. The calculation is shown below.

Main Line Process Calculation

$$\text{Number of processes} = \frac{\sum CT}{\text{Takt of process}} = \frac{2934 \text{ sec}}{399 \text{ sec}} = 6 \text{ processes} \quad (5.1)$$

Sub Line Process Calculation

$$\text{Number of processes} = \frac{\sum CT}{\text{Takt of process}} = \frac{1197 \text{ sec}}{399 \text{ sec}} = 3 \text{ processes} \quad (5.2)$$

When in full production, it was found that the daily operational availability (OA) achieved at this sewing section was only between 43% and 55%. From the analysis of this data, the indication is that the process is not meeting the daily target and score as initially set out. The objective of the study is to clarify the measurements, indicate factors leading to the sewing assembly process being unable to meet the score and rebalance the process being studied.

5.6.1.3 Initial Operational availability and processes cycle time for bottlenecks

Use of process standard times to initially balance the production process initially led to bottlenecks in certain processes. There were processes that were cycle times at processes that were below takt time and other processes that were above. Upon the start of production and analysis of the line, it was found that the line was not able to meet the score required. Even with all manpower present and material requirements present at the line side, the daily score could not be improved at this sew cover assembly line. Operational availability (OA) can be described as the percentage of time that the equipment or assembly line can operate properly when it is needed for production. OA of this line was targeted at 89%, actual OA was between the range of 43% to 55%. This was the main cause of delays in the seat assembly process and caused the most downtime to the final assembly line.

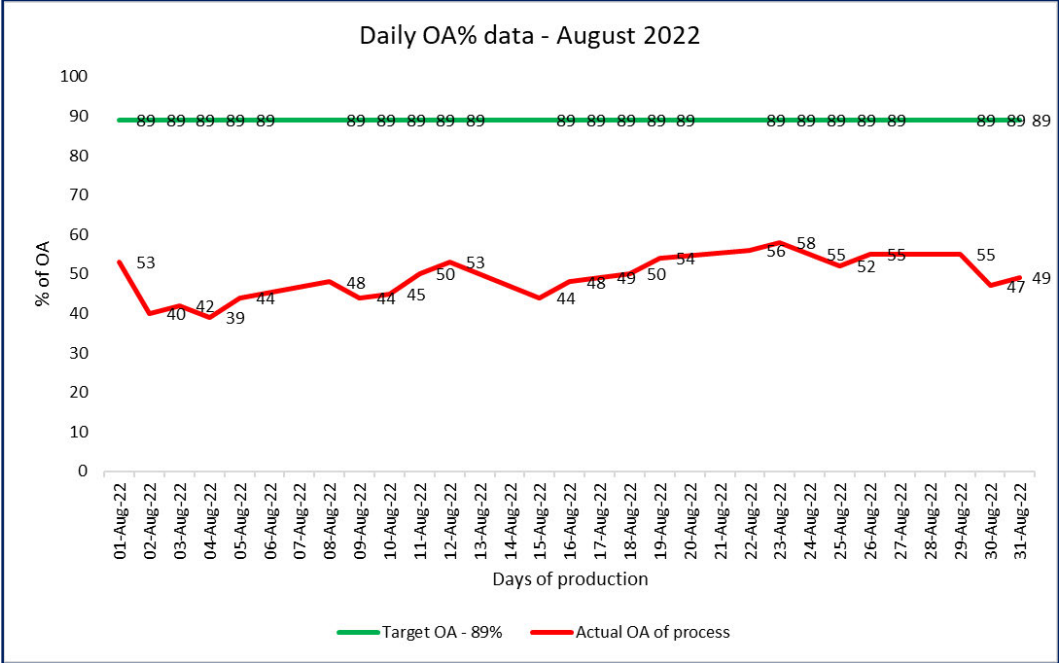


Figure 5.34: Daily data for August 2022

Upon investigation at the sew cover assembly line it was found that target OA was not being met daily. Two consecutive months of data were extracted and shown graphically

in Figure 5.34 and Figure 5.35. These graphs show the score target per day, the plan and actual OA, as well as the daily trend of OA achieved.

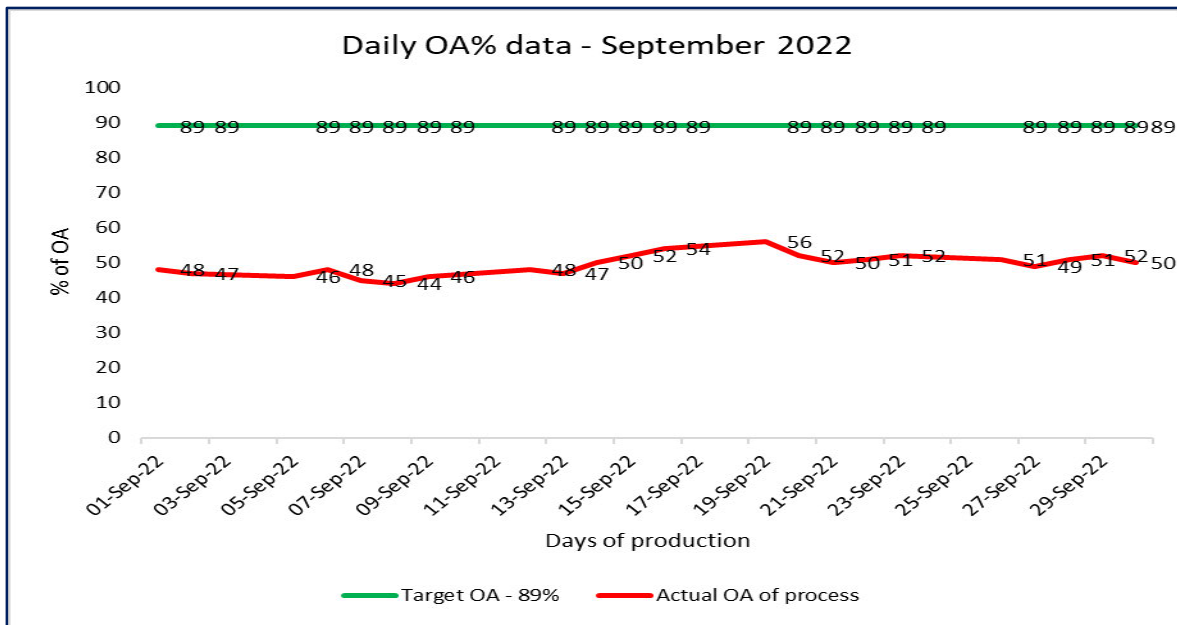


Figure 5.35: Daily data for September 2022

Further process investigation of the line and video analysis of elements showed us each process delay and the bottlenecks. Daily volume was set at 65 sets a shift. The calculated takt time for the process is 399 seconds. Cycle checks were done at 5 cycles per process to give us an indication of the bottleneck processes. The cycle checks are summarised below in Figure 5.36 and graphically shown on a bar graph to visually show the bottleneck processes. The processes above the takt time in dark blue indicates that these are the bottleneck processes which are above takt time.

The largest candidate rule was used to calculate the balance delay. Here the assignment of work elements to stations is based on the amount of time each work element requires to be completed. The balance delay was calculated for the above line and is shown below. Balance delay can be described as the amount of time lost due to imperfect balancing as a ratio. A balance delay of zero indicates a perfect balance. The balance delay was now calculated, and the above figure was given.

The production line has nine stations (three in front sub and six in the front main). Work content time to assemble the cover before any improvement is 67.15 min (4044.4 sec). The production rate per hour is 4 units per hour. The proportion uptime = 0.89 and reposition time = 10 sec.

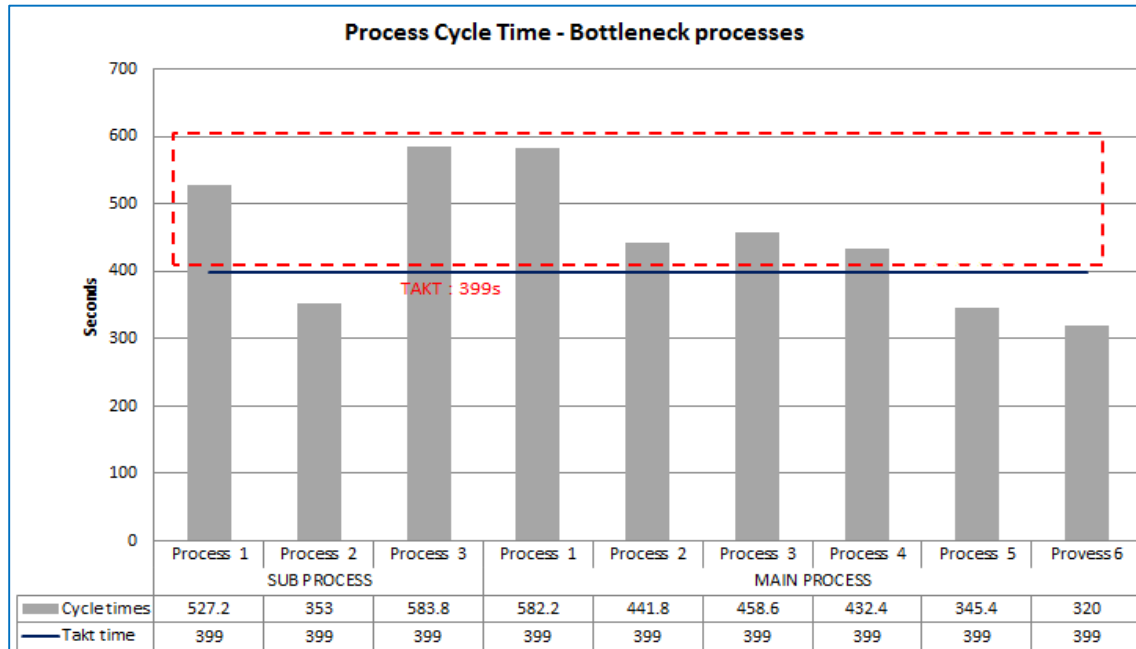


Figure 5.36: Cycle time checks to determine bottleneck in processes

$$T_c = \frac{60E}{Rp} \quad (5.3)$$

where T_c is cycle time of the line in mins/cycle, E is the line efficiency, and the constant 60 converts hourly production rate to cycle time in mins.

$$T_c = \frac{60(0.89)}{3} = 17.8 \text{ min}$$

$$T_c = T_s + T_r \quad (5.4)$$

where T_r is repositioning time and T_s is service time

$$T_s = T_c - T_r = 17.8 \text{ min} - 0.167 = 17.64 \text{ min}$$

$$\text{Balance delay, } d = \frac{wT_s - T_{wc}}{wT_s} \quad (5.5)$$

where w is the number of workers and T_{wc} is total work content time

$$d = \frac{(9 \text{ workers} \times 17.64 \text{ min}) - 67.15 \text{ min}}{(9 \text{ workers} \times 17.64 \text{ min})} = 0.58 = 58\%$$

This calculation shows that the balance delay of this line is 58% which demonstrates a huge line imbalance.

5.6.1.4 Implementation of possible solutions, reduction of Muda and rebalancing

A comparative analysis was also conducted on the productivity and efficiency before line balancing and after implementing the new rebalanced line for each process. Pattern description, fabric types and color were noted. The leather variant was chosen for this study as this particular material type was the high work content variant. Thicker material meant difficulty in handling and with this a higher cycle time needed to achieve the process elements. These new elements and cycle times were done at the process line side and with actual employees. These process cycle times were then used as a base line for the process improvement. This was done to ensure all processes and elements are accounted for when each process is being rebalanced.

Time studies were completed with the analysis of value-added, non-value added and Muda identification. Value-added elements can be described as elements that directly add value to a part being assembled. Non-value-added elements are needed to be carried out so that the value-added elements can be completed but do not add any value to the product being assembled. Non-value-added elements cannot be eliminated but can be reduced. Examples of non-value-added elements are picking up a screwdriver, leaving a wrench aside etc. Muda can be described as “waste” being part of a process. The elimination of waste at processes can make a substantial impact on manufacturing companies. By doing this, higher performance enhancement, improvement in delivery and quality and reduction in manufacturing costs are guaranteed. The most common Muda in manufacturing identified are motion, transportation, defects and waiting time.

Analysis of each process and elements summarised between value added, non-value-added and Muda is summarised in the bar graph shown in Figure 5.37.

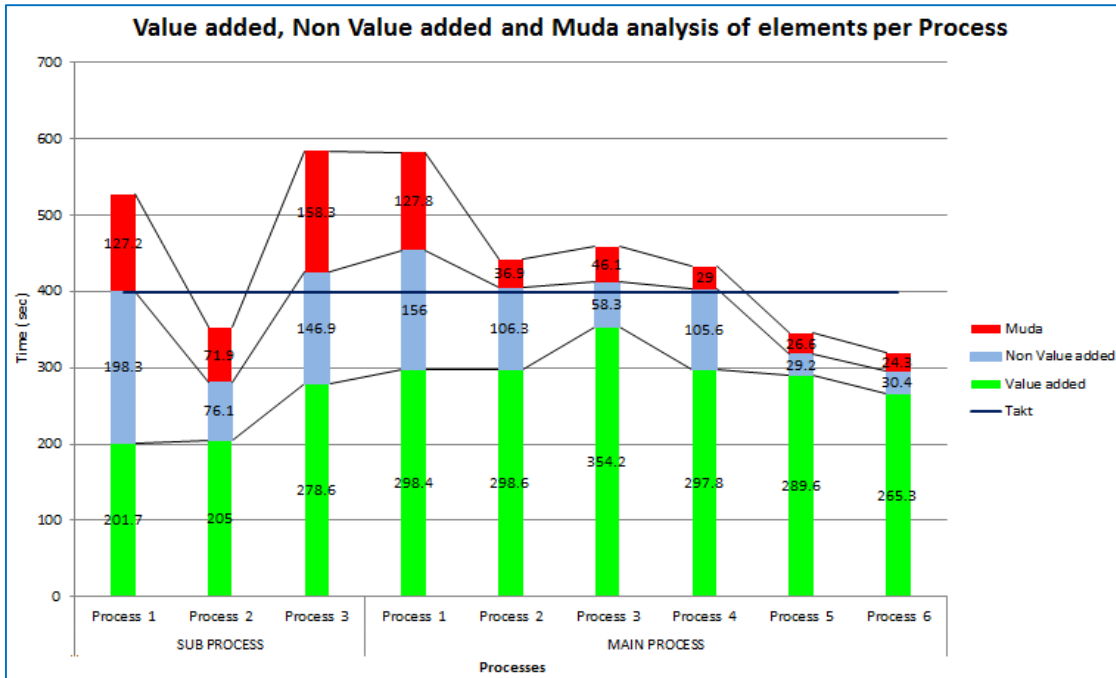


Figure 5.37: In-depth analysis of process elements of the line being studied

This information was then shared with all departments involved. This gives us as industrial engineers, an overall view of the process and where we can begin improvement strategies. Here in the non-value-added category, elements such as picking up a piece of material, cutting threads on a sewn item, place aside are some of the elements that cycle times could be reduced.

For process improvement, issuing a new scissor to a member to cut threads of sewn items faster and arranging parts on the conveyor strategically so that the member does not have to swift through items to find needed pieces to assemble the cover. Muda elements were reduced to their maximum. Elements such as turning around to pick up pieces, and process stands were fabricated to keep parts near to each process to prevent the member from walking to fetch parts. Machines were also moved closer and orientation of the machine was changed to ensure there were reduced steps when picking up pieces from the process line. After these changes, the elements with reduced CT were calculated and is shown below in Figure 5.38.

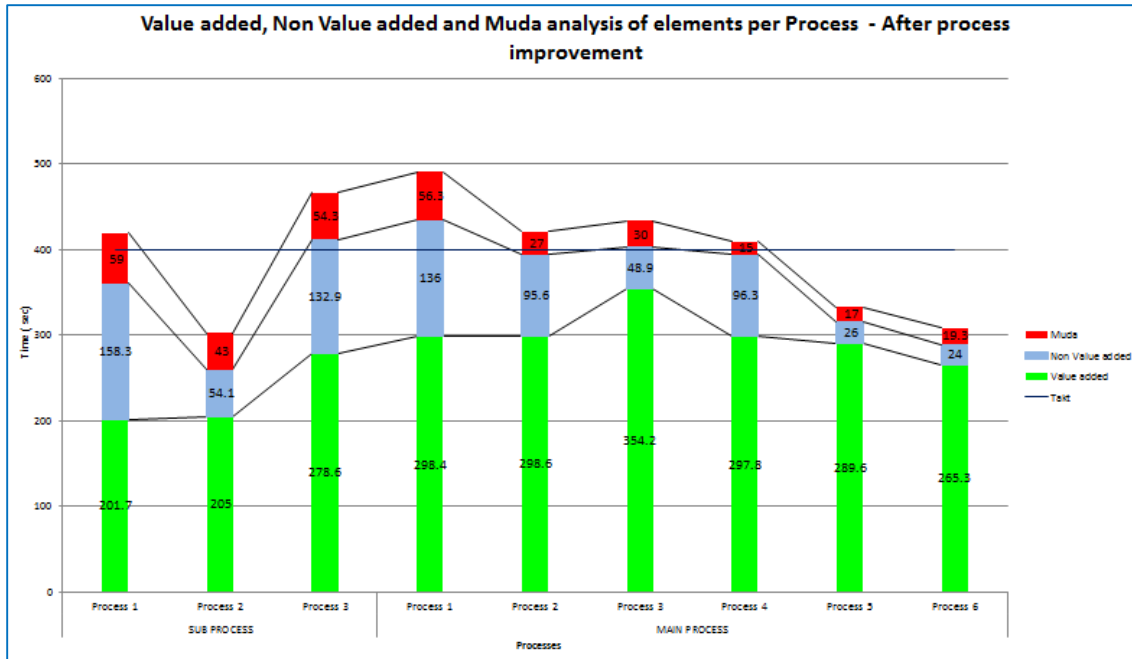


Figure 5.38 : In-depth analysis of elements per process- after kaizen improvements

With these new cycle times, elements were then rebalanced and re-distributed between processes taking into consideration different machine types. Workers were placed in different work stations based on operation sequence, the experience of operators, machine types and a standard time for each station was given to line management. The line was rebalanced, and new elements were taken from time studies. The new balanced sewing assembly line is shown in Figure 5.39.

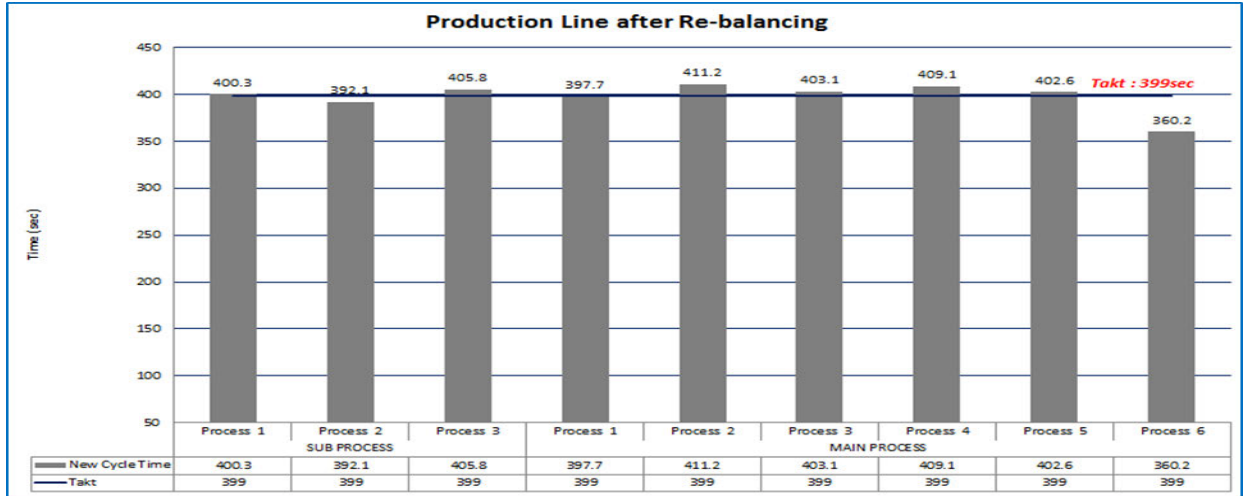


Figure 5.39: New cycle times per process after rebalancing

With these small improvements, Muda and non-value-added work was reduced, giving us the graph below. After full implementation at the process line side, the process was then observed and the results for October, November and December were tracked and shown in the following line graphs below. Process OA has increased by 20% after kaizen and rebalancing. Although target OA was not met, continuous improvement will be done on a weekly basis to achieve target the score.

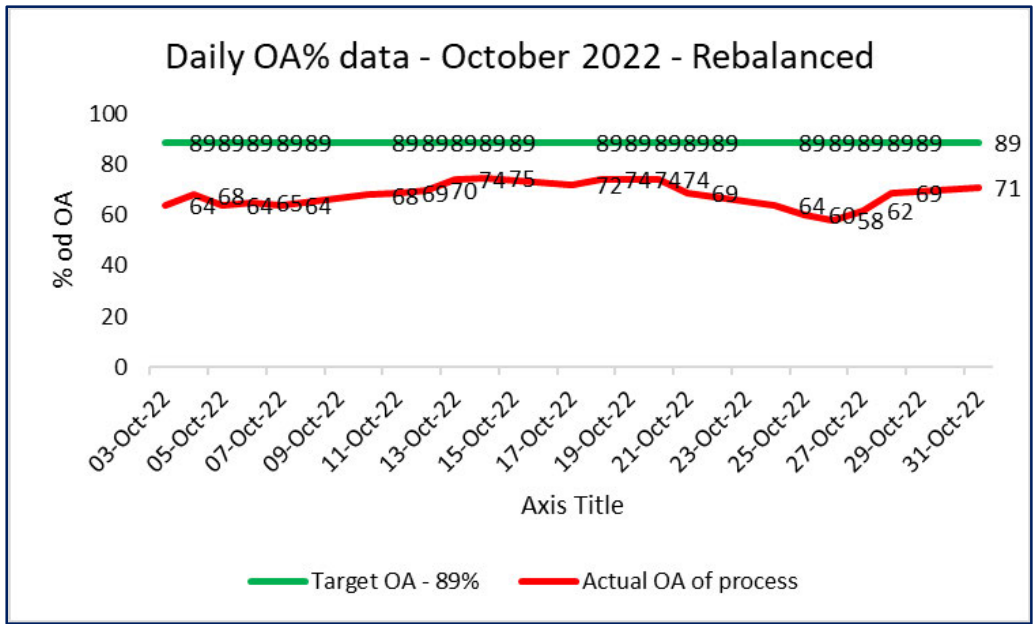


Figure 5.40 : Daily OA improvement after Line balancing for October

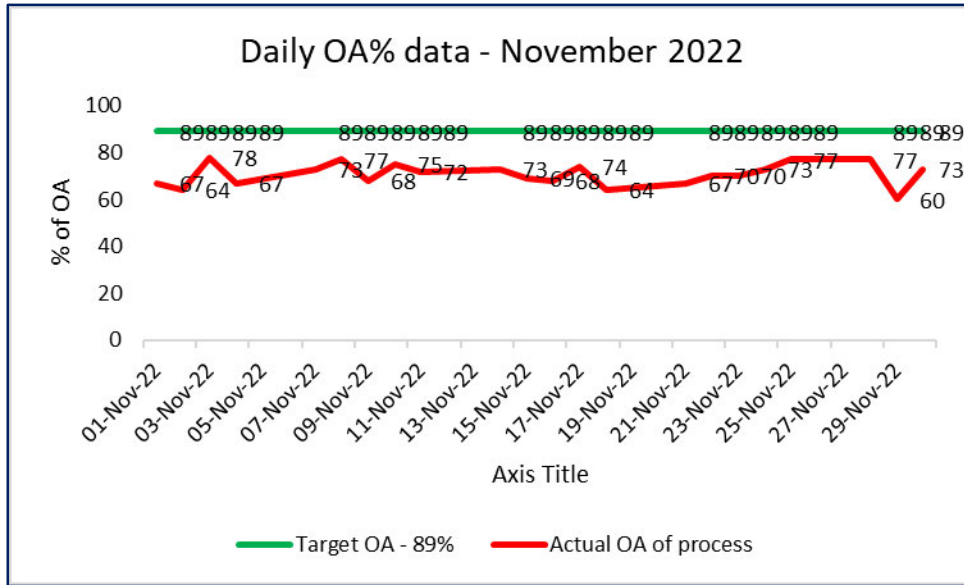


Figure 5.41 : Daily OA improvement after Line balancing for November 2022

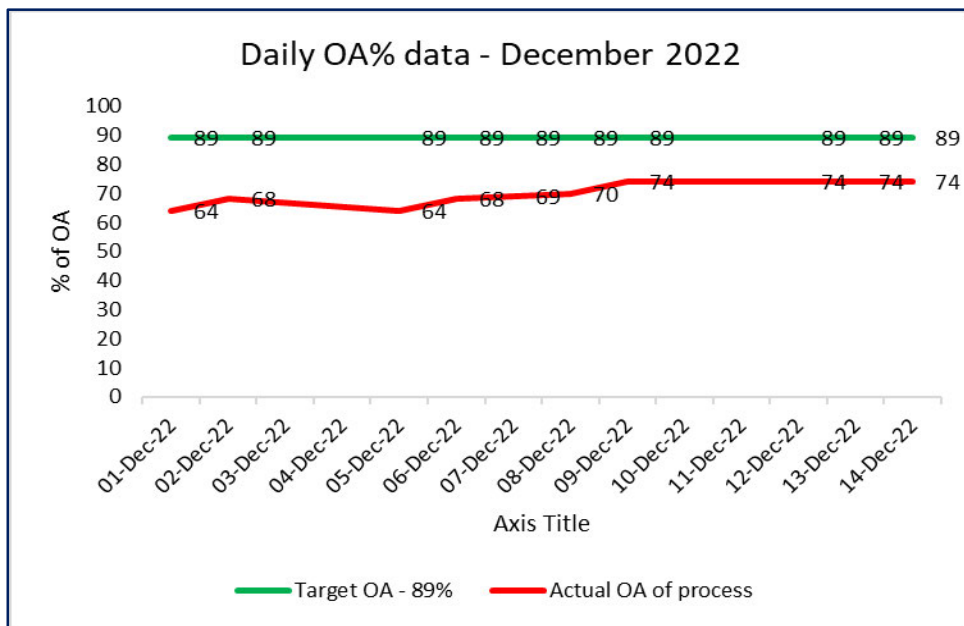


Figure 5.42: Daily OA improvement after Line balancing for December 2022

Only half the month of December was worked due to scheduled plant maintenance shut down. The new balance delay was calculated, and the new information and calculations are shown below. The production line has nine stations (three in the front sub and six in the front main). Work content time to assemble the cover before any improvement is

59.70min, this is after kaizen and rebalancing. The production rate per hour is 6 units per hour. The proportion uptime = 0.89 and reposition time = 6 sec.

$$T_c = \frac{60E}{Rp} = \frac{60(0.89)}{6} = 8.9 \text{ min}$$

$$T_s = T_c - T_r = 8.9 - 0.1 = 8.8 \text{ mins}$$

$$d = \frac{wTs - Twc}{wTs} = \frac{(9 \times 8.8\text{min}) - 59.70\text{min}}{(9 \times 8.8\text{min})} = 0.25 \text{ or } 25\%$$

This calculation shows that the new calculated balance delay is now at 25%. With continuous kaizen and elimination of further Muda at each process, the balance delay can further be decreased.

5.6.1.5 Results of improvement

The bottleneck process is one of the most common factors of downtime and inefficiency in manufacturing processes and limitations on throughput. Without an in-depth analysis of process elements and work-study, it is often difficult to determine these bottlenecks for them to be evaluated. Line rebalancing often irons out these bottlenecks and ensures that there is a smooth flow of material from the start to the end of the production line. Line balancing does not just assist a production line in meeting their targets but also assists in achieving a few management objectives, including continuous improvement. Ishikawa diagram and investigation assisted in determining the other factors that played a role in the OA inefficiency. This is an improvement item that covers all aspects of a production line and can be quite useful in production-related issues. When the line was rebalanced after determining the bottlenecks, the balance delay was decreased by 33%, and OA% was increased by 20%, thus reducing the downtime at the final seat assembly line.

Even though the target OA was not reached, there are still many process improvement items to be continued to reach desired OA. Continuous work study analysis to be continued and non-value added and Muda to be reduced further. Training is to be scheduled for each member on the sewing assembly line, and each member is to be evaluated based on skill, efficiency and time. By doing this, the more experienced and trained operators are on the assembly line and achieving the desired OA of 89% is much more achievable. Kaizen items such as work stand and work side tables are to be placed

at the process to ensure all parts required by each station are within reach of each member. Continuous reshuffling of process elements and simulation trials to be done to ensure the process is structured efficiently and effectively.

5.6.2 Andon System improvement at tier-one supplier

The visual indicators for the process are not effective with regards to alert line management that there is a deviation from standardised work. Hence it was imperative to develop an andon production management system to improve the efficiency of tracking of output scores.

5.6.2.1 Process flow at cover assembly line

An automotive assembly supplier based in South Africa, manufacturers components for one of the market leading car manufacturers in the country. At the sewing production assembly line, it was found that the production output of scores was not recorded hourly by the line management. This showed a struggle in analysing the hourly scores as line management. This showed a struggle in analysing the hourly output scores as the line management could not determine the struggles being faced hourly by the production line. Production scores was not being met and this posed a difficulty in determining the factors in determining what was wrong.

There are two assembly conveyor processes known as the cushion cover assembly and the back-cover assembly. Both processes are run by conveyors at a speed of the volume requested by the customer. Each conveyor has eight processes on the conveyor. Each process has one person stationed at it. Once each line completes the assembly of a cover, this cover then goes to the final point on the cover which is the quality inspection. At the quality inspection process (QC), the cover is checked before going to the finished goods storage. At the finished goods storage, the goods are then taken by the next process when needed. Figure 5.43 below shows the process flow of the line.

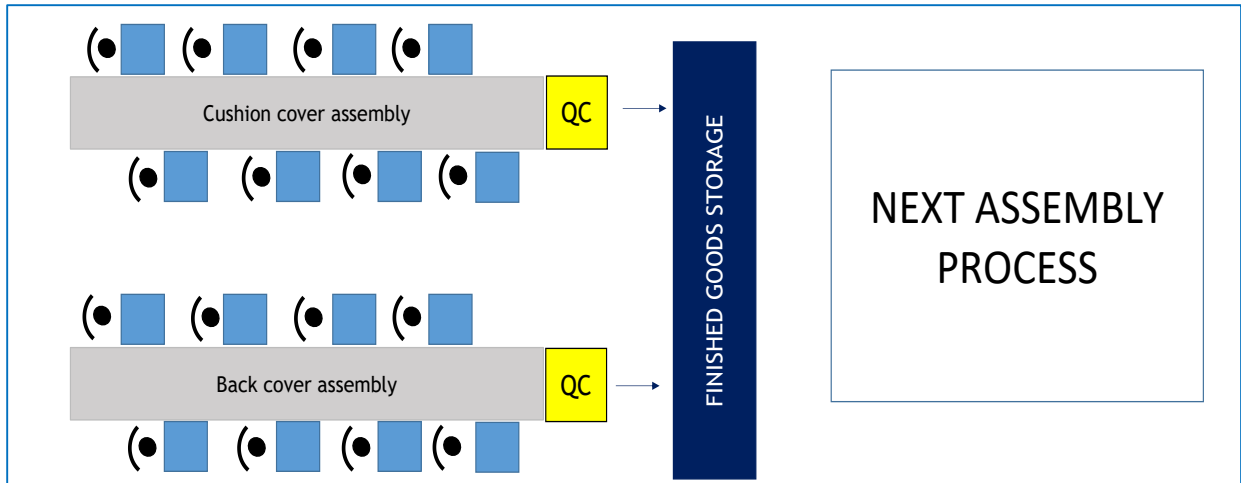


Figure 5.43: Production line shown diagrammatically

5.6.2.2 Potential cause of not being able to record production scores

Each line has production sheets in which hourly information needs to be recorded. This assists management to determine if the production requirement is being met at any part of the day. Unfortunately, this was found as a difficulty by the line team leader and group leader as there was many other tasks required of them.

The requirement and production standard of the company is that production records scores of outputs hourly as well as the quality inspection department. Quality inspection records how many covers have been checked for a day. Production requirement a day is of 240 pieces. Data was requested from the quality department of the number of scores recorded daily for the month of November 2022. These scores were then compared to the recorded production scores by production. The compared scores per department is shown below in Figure 5.44. The blue scores indicate the scores recorded by production, the yellow bars indicate the scores recorded by quality and the red line graph indicates the target required by the line to produce.

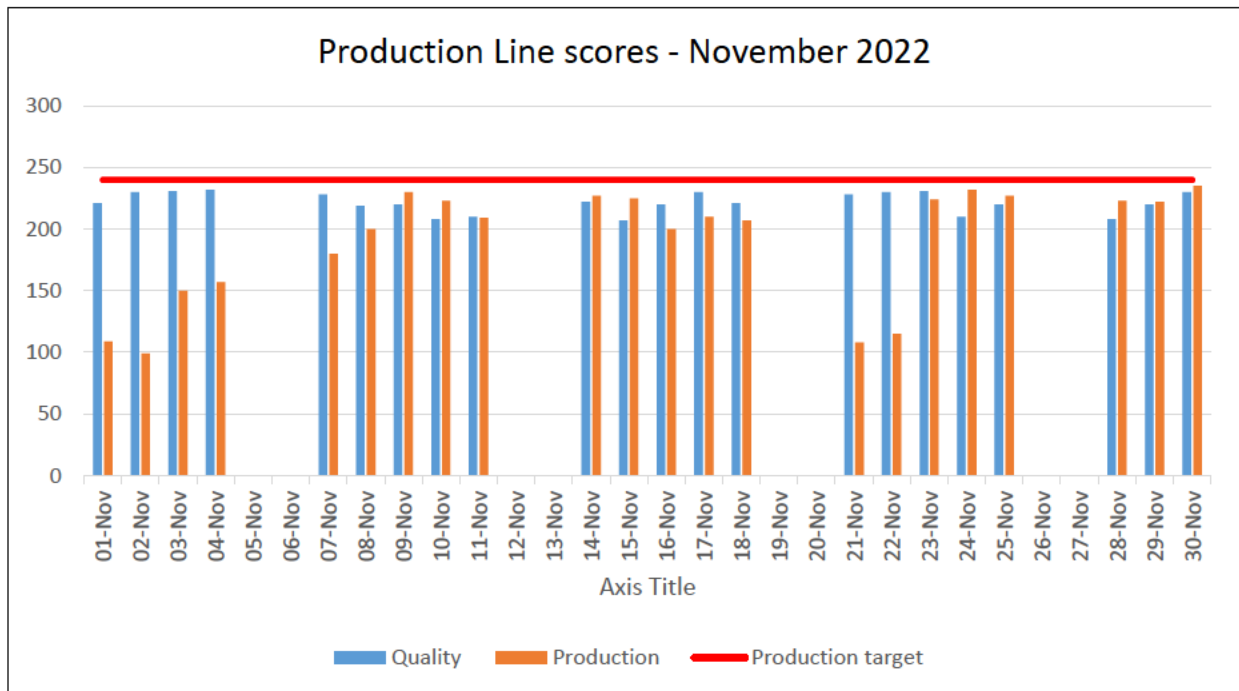


Figure 5.44: Bar graph showing the different scores captured by the quality and production department against the line requirement

As visible, scores were not aligned and not a true reflection of production pieces being produced. There were days where production scores are higher and days where the scores captured by quality was higher. Actual scores could not be presented to management as true reflection of scores could not be recorded. Downtime analysis was difficult to do as real data of what prevented the hourly score from not being achieved could not be determined.

A fishbone diagram assists in determining root causes of issues of line constraints and finding possible solutions to the problem areas. A fishbone diagram is broken up into six categories, man, method, material, machine, measurement and environment. The Fishbone or Ishikawa diagram in Figure 5.45 below shows factors that affected the production line in not being able to record and track the hourly scores.

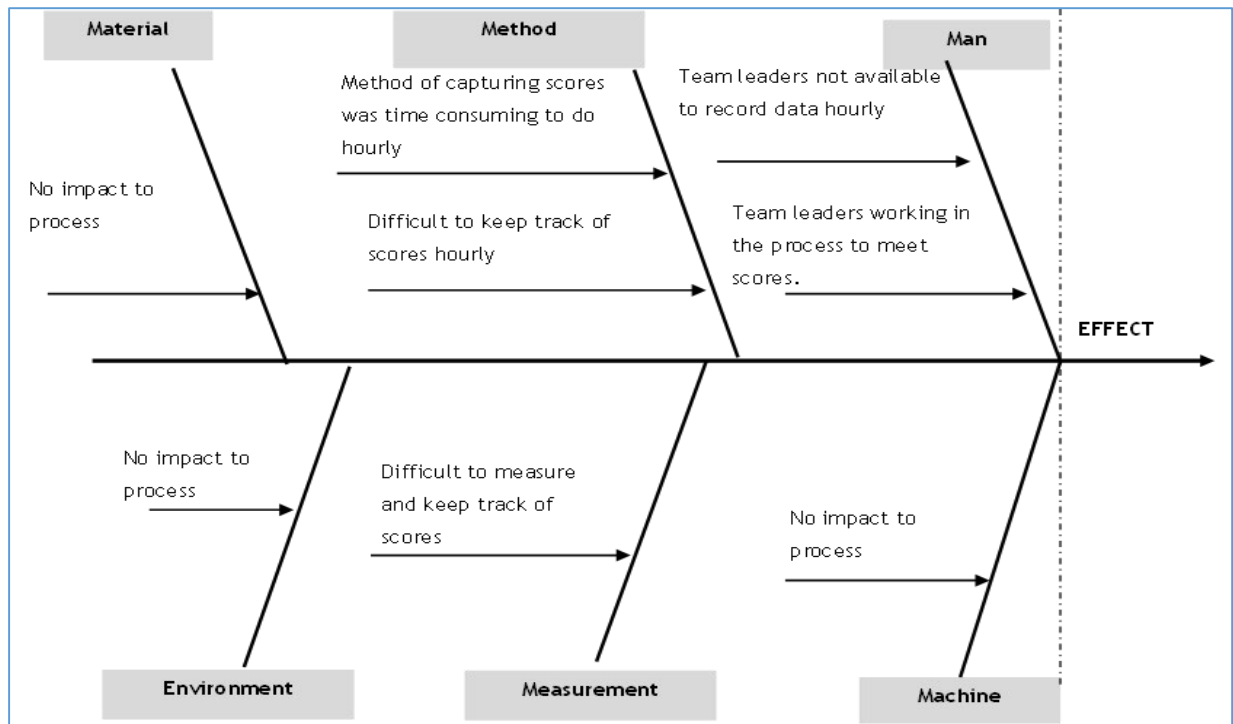


Figure 5.45: Fishbone diagram of what prevented team leaders and group leaders in capturing scores

From the fishbone diagram we can see that are factors under the method, man and measurement category in which scores could not be captured. Under man, we determined that the team leaders who oversee capturing the scores found it difficult to do as there are other tasks required of them. When there is high absenteeism of the line, they must work on the process. This prevents them from capturing the scores. Under measurement, we found that there is no easy way of capturing scores, this took time and was difficult to do.

5.6.2.3 Improvement of principle 8

When consolidated with manufacturing and the quality department, it was agreed that an easier and technological approach should be used as this would be an efficient and creative way of capturing scores. With this research was done and a proposal discussed with the relevant departments. The approach used was installing an automatic production management andon system.

An andon cord or button is used to generate alerts to the line management. Here at each process, a push button for “CALL TEAM LEADER” and “WORK COMPLETE” was

installed. The call team leader button is for the member to call the team leader without moving from their station if there is any abnormalities or breakdowns. The WORK COMPLETE button is pressed after each cycle done by a member. So, every cycle of the calculated takt, ideally it should be pressed to confirm each member at each process has completed their work cycle. If this not the case, the work complete starts flashing to indicate to the member at the process that she is running behind. This is also displayed on the screen showing which process is now delaying the overall line. This screen is displayed at the end of the line or at any point that is visible to line management or management walking by. While this is being shown, a melody is also played for the line management to draw attention to the screen to visually see which processes are behind the schedule and takt time. Using the PDSA Cycle, this was followed through. This is described below in detail of how implementation went about in Table 5.35.

Table 5.35: PDSA cycle used to install an andon system

Step	Description	Responsibility	Status
Plan	<ul style="list-style-type: none"> • Create a schedule of implementation • Source a contractor to understand the activity 	Industrial Engineer	Completed
Do	<ul style="list-style-type: none"> • Implement the Andon system at the sewing assembly line 	Industrial Engineer	Completed
Study	<ul style="list-style-type: none"> • Study and observe that the push buttons are working 	Industrial Engineer	Completed
Act	<ul style="list-style-type: none"> • Train production members on how to use process push buttons • Monitor condition and screen display. 	Production management and Industrial engineer	Completed

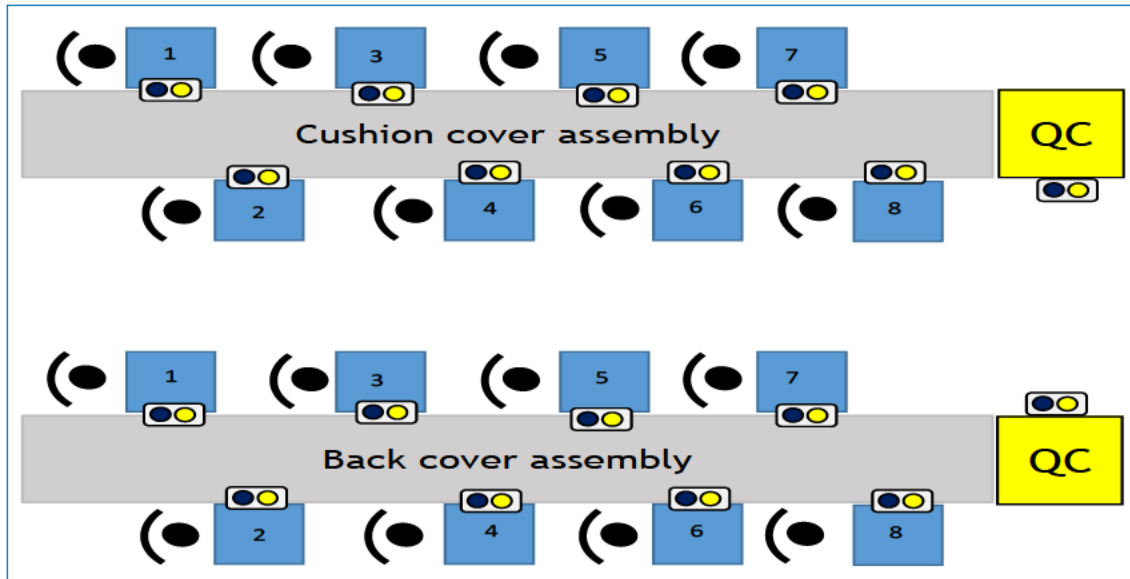


Figure 5.46 : Line set up with andon buttons at each process

Each process was set up with a set of andon buttons at each process. This is shown above in Figure 5.46. If there was an issue, the member at each process would press the yellow button – the call button. This was displayed on two LED screens situated at line side. There was one screen dedicated for the cushion cover assembly line and another screen dedicated for the back-cover assembly process. After each member at each process was completed with each piece of sewing at their process, there were required to press the blue button to indicate a piece was complete. A set of andon buttons was also installed at the quality station as it also records each day's data and could easily be retrieved on any day as the system records the information automatically. This was required as manufacturing confirms how many units they produced and so does quality.

The reason as to why this is separated and quality final counts are displayed on the andon is specifically because quality does the final count and are the last to touch the product before final shipment to the finished goods storage. For example, manufacturing can state that they manufactured 20 products and hour and quality only counts 18 units. The variance of the 2 components can either be rework or units scrap. If there was an issue, any process would press the call button and it would display on the screen as shown below in Figure 5.47.

Cushion	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6	Process 7	Process 8
	-	TL CALL	-	TL CALL	-	-	-	-
Back	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6	Process 7	Process 8
	-	-	-	TL CALL	TL CALL	-	TL CALL	-

Figure 5.47: Display for Call button

The display of each process assembling a component is also shown in Figure 5.48.

OVERALL LINE PRODUCTION SCORES									
Cushion	PROCESS	1	2	3	4	5	6	7	8
	TARGET	240	240	240	240	240	240	240	240
	ACTUAL	233	222	220	219	230	222	224	219
Back	PROCESS	1	2	3	4	5	6	7	8
	TARGET	240	240	240	240	240	240	240	240
	ACTUAL	234	236	230	222	231	217	220	222

Figure 5.48: Production score tracking per process

The overall line andon display is shown in Figure 5.49. This made it extremely easy to track scores and improve line efficiency. This was easy to view by any management individuals walking past.

CUSHION ASSEMBLY COVER DISPLAY SCREEN			BACK ASSEMBLY COVER DISPLAY SCREEN		
	Cushion	Back		Cushion	Back
	Assembly	Assembly		Assembly	Assembly
Plan	240	240	Plan	240	240
Actual	222	232	Actual	222	232
Calculated OA	93%	97%	Calculated OA	93%	97%
Takt time of the line	1,89min		Takt time of the line	1,89min	

Figure 5.49 : Andon display screens at the process

Installing an automated andon system posed many benefits for the line management. Many of which are listed below:

- Assisted the managers in knowing real time data at any point in time.
- Data from the line is recorded on the system which is linked to the company drives. Each shifts data and downtime were recorded so at any point in time, it could be back tracked.
- Assisted management in determining the reasons for inefficiencies. With the downtime analysis reports, many of the process delays were due to line stoppages of no parts or maintenance issues. This was resolved internally and addresses.
- Data and piece count was corrected and were now easy to keep track of.
- Each process was also evaluated to see which process was a bottleneck or which process did not meet the scores required for the shift. With this process improvements were done to reduce the effects of bottleneck processes on the line.
- If a process did not press the work complete button, the conveyor would then stop to indicate work delay at that process.
- If there was a maintenance issue, the member at the process would then press the work call button and indicate on the andon that it was a maintenance breakdown that occurred and how much of downtime occurred.

Three months of data was captured and this gave a more realistic view of the actual production scores being captured. This shows the real time target and production scores being captured. The production scores captured by the Andon system were verified and compared with the quality department. This showed us that the record of production scores was correct.

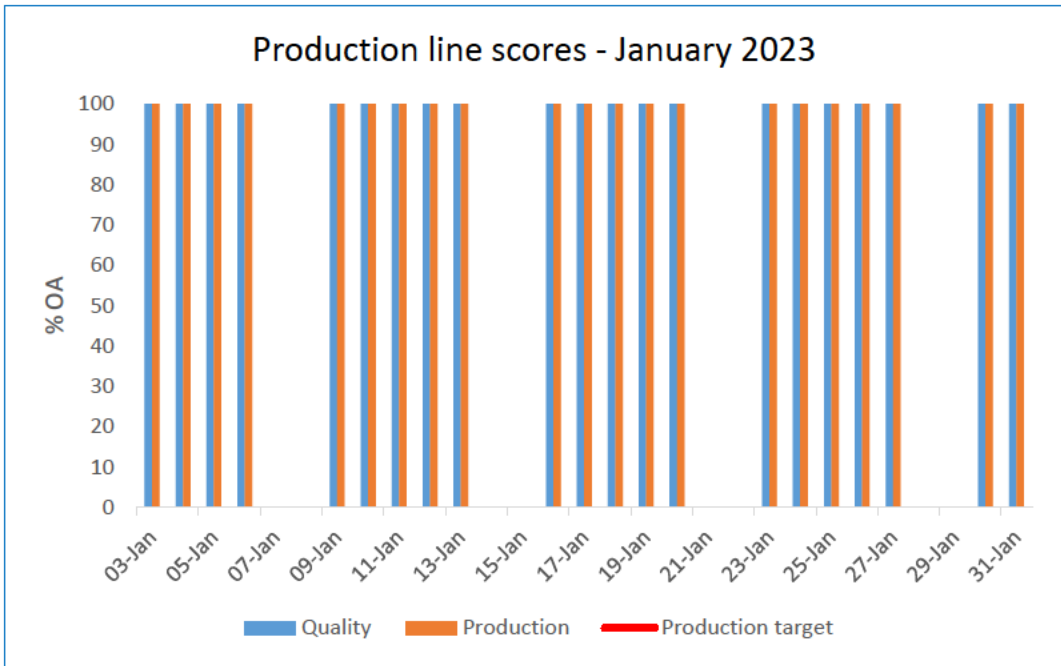


Figure 5.50 : Production scores captured by the Andon in January 2023

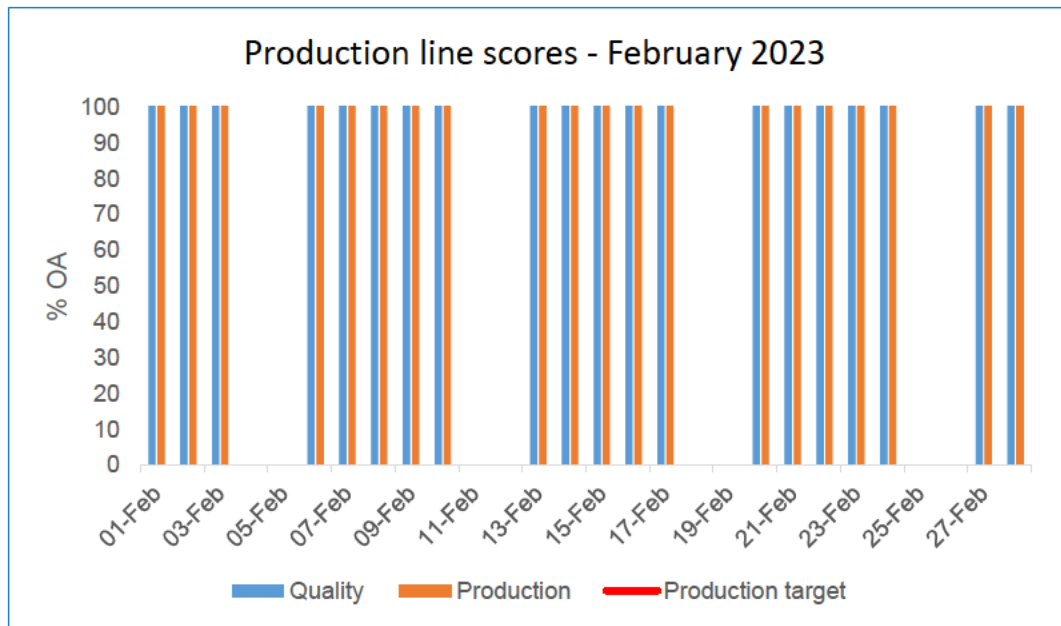


Figure 5.51 : Production scores captured by the Andon in February 2023

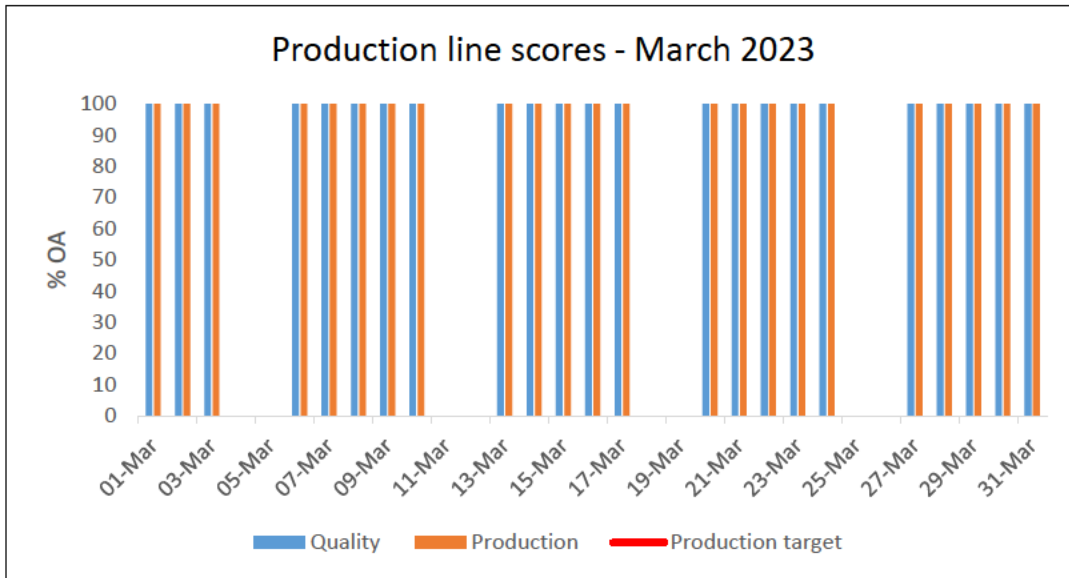


Figure 5.52 : Production scores captured by the Andon in March 2023

From the analysis reports, we could see that there were many issues affecting the line productivity. Each issues are listed below and the countermeasure of each item was also addressed. This is shown in Table 5.36 below.

Table 5.36: Downtime analysis ad countermeasures

Downtime	Description	Countermeasure	Status
Maintenance	Poor lead time to break downs. No dedicated technician for the area	Hire a dedicated maintenance technician for this process to be dedicated to. This will enable a fast response to any breakdown of the line	Completed
Process delay	It was found that there were two process on each line (Cushion and back assembly) that were bottlenecks	Restudy and balance process to ensure there are no stoppages or processes falling behind.	Completed

The reports from the andon were helpful in addressing issues that occurred and putting countermeasures to ensure an efficient process.

5.6.2.4 Results of improvement

Many companies are still very traditional when it comes to process planning as well as improvements. Installing an Andon system at the end of the process as well as simple buttons to control the process at each stage makes it easier to control as well as to track and monitor production efficiency hourly. With this, this enables the production line management to easily deal with other tasks needed on a daily basis. Even though an andon system was implemented there are still many improvements that can be done. Some are listed below:

- Add on logistics call button at each process.
- Add on delay button at each process
- Add on maintenance call button at each process.

By breaking it down further, we are even more able to distinguish the issues affecting productivity. The production visualization system or the Andon system was successfully implemented at the line side. This assisted greatly at responding to issues at each process to ensure the line runs efficiently.

5.7 Framework for tier-two supplier for successful implementation of principles

The fifth objective of the study was to develop a framework for optimal Toyota Production System implementation by for the tier 2 supplier. Results from quantitative analysis demonstrated the lower results for the principles hence it was imperative to develop a framework for the tier-two supplier.

For the Toyota model principles to be implemented successfully, there are underlying support structures needed to be put in place for any activity to have a beneficial outcome. Figure 5.53 below shows you simply the main gears for any improvement to be successful. The diagram comprises of three aspects:

1. Support from management: If top management drives any improvement, lower management have no choice but to follow. This drives managers down the hierarchy to follow as well as to lead teams on the lower managerial level.

2. Knowledge and strong teams: employees will not carry out improvements if they are not fully knowledgeable on the principles as well as the benefits of successful implementation. All employees should be guided on all principles so knowledge can be passed onto other employees for information sharing. Strong teams are also part of this gear. Strong teams are needed to drive improvements and kaizens, to conduct training as well as ensure proper countermeasures are implemented and monitored.
3. Successful implementation of the Toyota model: With the other two gears actively moving forward, these gears will get the successful gear rotating.

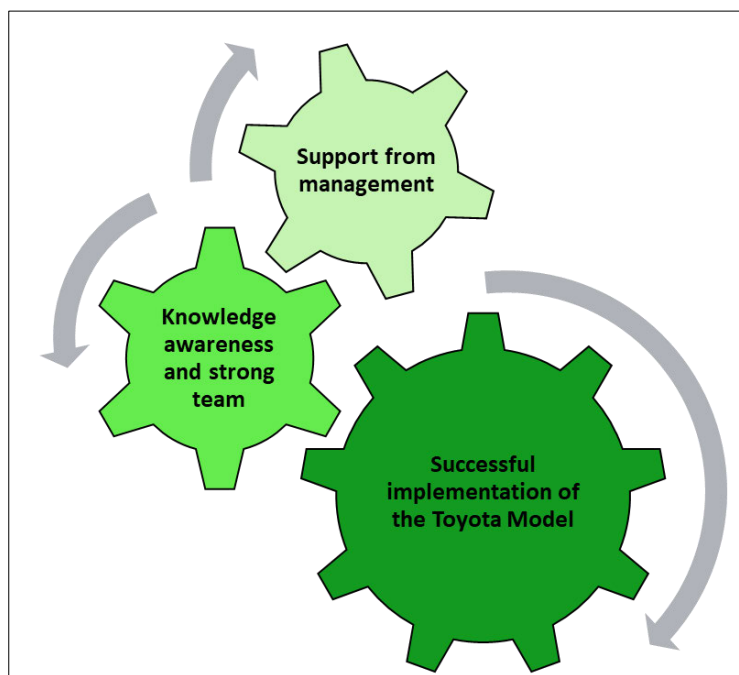


Figure 5.53: Gear model for Toyota way principles (Authors' own)

A more in-depth framework was created for each of the 14 principles of the Toyota way model. However, from the analysis, it was imperative that this model be improved on, hence the author has created this framework as well as added an additional three principles making it a collective of 17 principles. This is shown in Figure 5.54. The additional principles are described as follows:

- Principle 2 (New): Overall management participation and direction of organisation. The addition of this principle describes the support of higher management in shop floor activities. They are also the stirring force behind the ship, hence activity plans

and direction for future sustainability of the business to be share with management lower down in the hierarchy.

- Principle 3 (New): Process management improvement drives to teams lower down. Kaizen workshops and continuous improvement activities to be driven by production management of the process. If assistance is required, this should be requested from higher management. Team leaders of the process should motivate and initiate members to participate in such activities.
- Principle 14 (New): Involvement of people at the process. Individuals at the process. Members based at the process are more aware of kaizens and continuous improvement initiatives to ensure any process runs efficiently as they are the ones whom are regularly at the process. This does not only relate to process improvements, but information sharing as well. Members at the lowest level to be kept in the loop on information regarding the business as they are the force at work.

Here each principle has keywords to enable the user to easily implement the principles. A more in-depth step by step framework guideline was also created and can be found in Appendix J. This is for a better understanding for any continuous improvement department, industrial engineer to easily implement in an organisation that has no experience in implementing these principles to be successful.

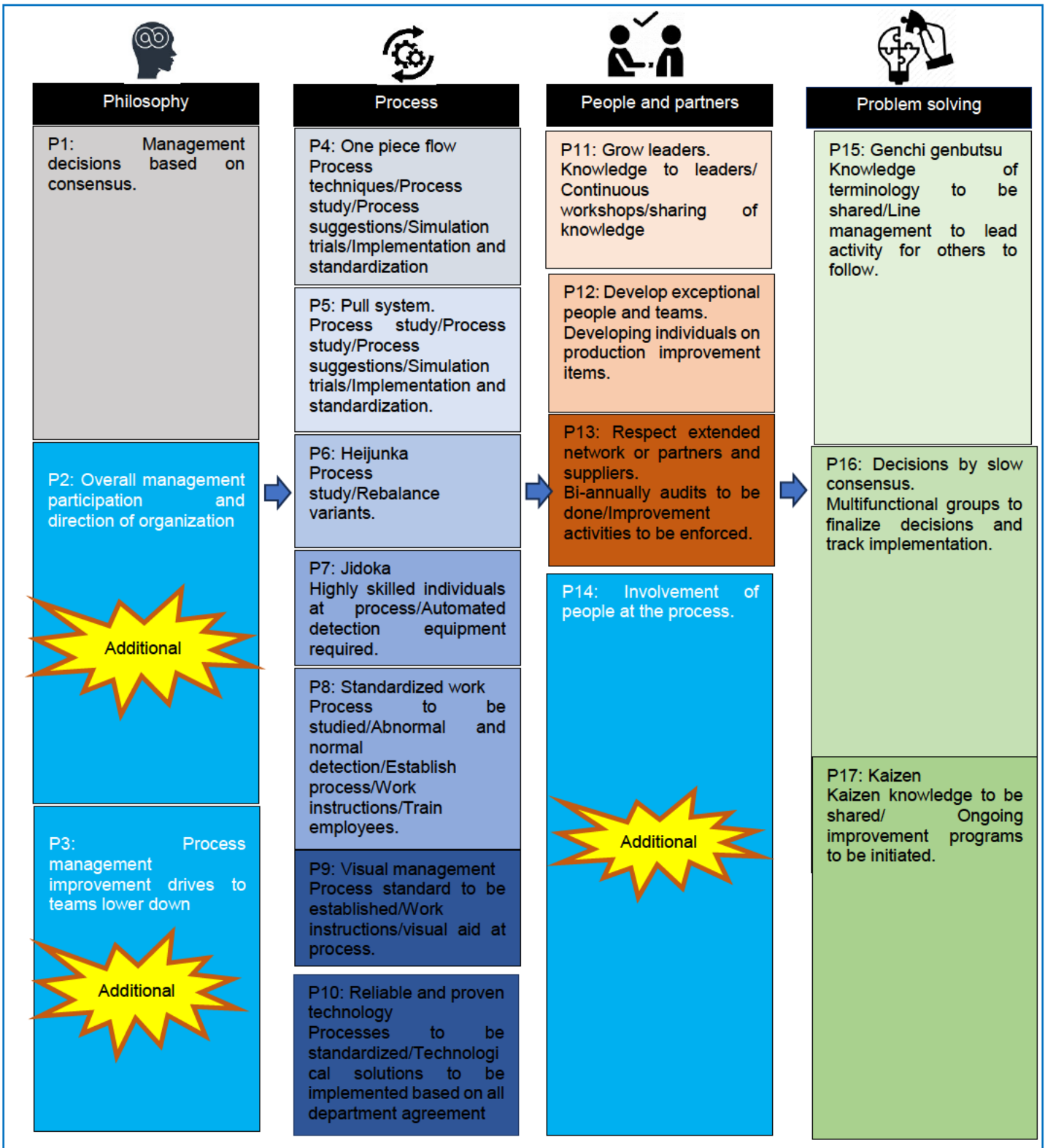


Figure 5.54: Framework for implementation of the 14 principles of the Toyota Model

5.8 Discussion of results

From the data statistics we can see that the tier-one company is more aware and have responded by agreeing or strongly agreeing for majority of the principles. Whereas in the tier-two company, many of the participants responded with disagreeing and strongly disagreeing for principles. This goes to show that Toyota production systems principles are carried out and implemented more successfully in the tier-one company as compared to the tier-two company. We were also able to deduce that the tier-two company are also not familiar with the different aspects and principles of the Toyota model. This is one of the first points mentioned in the literature states this. Dillon and Shingo (1989) speak about implementing TPS such that the external features of the system must be fully understood when applying the TPS principles so that it is successfully implemented. This point could be due to lack of knowledge or teachings of someone skilled in the implementation of TPS in the tier two supplier, limiting knowledge sharing and confidence in this topic within individuals in the organisation.

With the data collection it is easily visible that not all principles are fully understood at the tier-two supplier as compared to the tier-one supplier. From the quantitative results, we could establish the stronger and weaker principles of each supplier. We could also determine which principles were further apart and closer together in each organisation based on the mean descriptive values. The stronger principle of the tier-one supplier being Principle 1 and 12, Which is briefly management making decisions on long term philosophy as well as the principle of genchi genbutsu respectively this informs us that the company considers the future as well as solves problems at the source of occurrence immediately. Whereas in the tier-two supplier, Principle 1, and principle 7 (visual management) being the stronger principle in the tier-two supplier. This gives us insight that management does take the future into consideration, however actions of the implementation of the principles are not followed through.

Although the results of the mean descriptive values are higher in the tier-one company as compared to the tier-two company, there were many areas of improvement in the tier-one organisation. Two improvement items were investigated and improved on particularly being the process level of the Toyota model. Here, the line balancing technique, kaizen

principle and advanced technology was used to improve the process at this organisation. These small improvements yielded great efficiency improvement at the production process at this organisation.

5.9 Conclusion

In this chapter the results and findings relating to the feedback provided by the respondents at both sites were discussed. After reviewing the results and findings from the quantitative data, the research objective of identifying the current principle status of the Toyota model used by a tier-one and tier-two supplier was achieved. Through this, one could also investigate and distinguish which principles are stronger or weaker in the each of the suppliers. These objectives were accomplished by the quantitative research questionnaire that was used at each supplier which descriptive values were extracted from. The comparative analysis also revealed that all principles at the tier-one supplier had a higher mean value as compared to the mean values at the tier-two supplier. With these mean values, this enabled successful analysis of which principles needed improvement on as well as improvements were made based on this information. A framework from these descriptive values for future implementation of these principles was also created as well as a gear model for the Toyota model to be in motion. Recommendations for future work is discussed in the following chapter.

CHAPTER 6: RECOMMENDATIONS

6.1 Introduction

This chapter focuses on the research recommendations and conclusion from the quantitative descriptive data values established in the previous chapter. In this chapter, we will highlight the summary of research findings, recommendations for each supplier as well as future work for the Toyota model. We will also outline the research findings and information extracted from the descriptive information data.

6.2 Summary of research conclusions

The current production processes that characterize a tier-one and tier-two supplier were outlined. Value stream maps for the tier-one and the tier-two supplier were developed to provide an overview of the processes from the customer requirement to the manufacturing processes. Regarding the tier-one supplier, it was found that the processes at the tier-one supplier are characterized by too much waiting time, operators waiting for parts and materials to complete their processes. there were no alert systems for on time delivery at their processes. It was also noted that a minor of the processes does not meet production line targets. There were also many bottlenecks processes within the cover assembly production line at this supplier.

At the tier-two supplier, there is a long distance for parts to be transported to the processing station before being processed. A more effective process layout would be required to eliminate the muda of walking and transportation. Overall, the tier-two supplier is required to improve all current processes before implementing any further process improvement as many of their processes were not in optimal condition.

For determining the current status, it was found from the study that there are certain principles that are stronger and weaker in each supplier. Common principles that were stronger in each supplier was being Principle 1, Which is briefly management making decisions on long term philosophy as well as the principle of genchi genbutsu respectively this informs us that the company considers the future as well as solves problems at the

source of occurrence immediately. This principle was also found to be stronger in the tier-two supplier.

Even though process improvement initiatives were carried out, target OA for certain processes was not achieved. There were still many process improvement items to be continued to reach desired OA. Continuous work study analysis to be continued and non-value added and Muda to be reduced further. Continuous reshuffling of process elements and simulation trials to be done to ensure the process is structured efficiently and effectively. Additionally, it was found from the study that the production visualization system or the Andon system assisted greatly in the tracking of production scores, responding to issues at each process on time to ensure the line runs efficiently and effectively.

It was also found from the quantitative analysis and descriptive mean values that the results for the principles for the tier-two supplier were lower. With this, it was imperative to develop a framework to address the missing gap as well as countermeasures for easy implementation of every principle.

6.3 Recommendations

Recommendations for each supplier are explained below. These recommendations can assist the respective suppliers in the successful implementation of any principle. It is vital to propose recommendations for an effective and successful implementation of the principles.

6.3.1 Recommendations for tier-one supplier

Although the quantitative data and mean descriptive data was of a higher value as compared to the tier-two supplier, there are still many areas of improvement to consider. The lowest mean descriptive value was for principle 8, use of reliable and proven technology. This can be improved by investigating and searching for suppliers that specialize in technological advances in the manufacturing industry. Through this eye opener to the team, this can motivate engineers and employees to investigate other technologically proven installations to ensure processes are efficient. The second lowest was principle 9; to grow leaders. This can be achieved by organizing short training

courses on productivity and quality improvements to enhance their knowledge as well as skills. And lastly, the third lowest were for principle 11, decisions by slow consensus. This principle can be improved by training and forming an organisation group that assists and finalizes decisions concerning aspects beneficial to the company. The tier-one company should also commence with TPS or Toyota principal workshops to enhance knowledge not only for leaders, but throughout the organisation.

6.3.1 Recommendations for tier-two supplier

The following recommendations were made for the tier-two supplier:

- With the tier-two suppliers having lower descriptive mean values for all principles, there is much work to be done to improve the knowledge of the Toyota model and its principles throughout the company. The lowest mean descriptive mean value was for principle 12; genchi genbutsu. Strong direction from management is needed to drive this principle as this starts with top management. Going to the source of the problem not only assists in improving quality defects and issues but also subsequently improves productivity.
- Visit suppliers and partnering companies for possible areas of improvement to their plan or their own. By doing this, this shows wavering support for the betterment of each business.
- Having a work team focusing on process and standardization improvement. Here, teams will ensure processes are at their highest efficiency by reducing waste and implementing kaizens.
- Promoting kaizen in the organisation. By sharing knowledge and promoting the idea that the smallest kaizen is still a kaizen, any improvement can assist in the aid of the betterment of any process.

6.4 Future research

The Toyota model and Toyota Production systems in the manufacturing sector yields great advantage and benefits if successfully implemented. Although not all may have the same depth of understanding of the 14 principles, basic knowledge and implementation can bring about massive improvement to a production line. The following few areas can be used and investigated for future research.

- How to establish a Toyota production system culture around the principles for successful implementation?
- What additional techniques and principles can be added to the Toyota model that is more aligned with the South African automotive industry?
- How can the Toyota Production System be applied to the service industry?
- What underlying implications are there when implementing principles from the Toyota model or Production system?
- How can other industries apply the framework for a successful implementation of the Toyota model of principles?
- With the fourth industrial revolution and AI strongly gaining momentum, will the TPS Methodology still be relevant for the foundation of any improvement?

6.5 Conclusion

The first objective of the study was to identify the current production processes that characterize the tier-one and tier-two supplier. This objective was achieved by observing the process flow from both companies and then going to the drawing board to fabricate the value stream map. The value stream map from both suppliers explains the processes as well as cycle times. Kaizen burst which can be described as ideas of improvements were also highlighted on each value stream map for future reference and areas of improvement. This can be found in Chapter 4, starting from page 32.

The second objective of the study was to identify the current principle status of the Toyota Production System and Toyota model principles used by a tier-one and tier-two supplier. This objective was also achieved by using the quantitative research questionnaire that respondents from each company participated in and results from these questionnaires

assisted us in determining the level of knowledge and current principles being used by each tier.

The third objective of this study was to investigate which principles are stronger or weaker in either the tier-one and tier-two supplier. The quantitative data supported this objective as well as the descriptive mean values could assist in distinguishing which principles which were either stronger or weaker in each model. This was shown in a line graph for easy graphical analysis. Both the second and the third objective, are explained in Chapter 5 starting from page 38.

The fourth objective was to implement continuous improvement initiatives for the tier-one supplier. This was achieved from the kaizen bursts from the value stream map in Chapter 3. With this process map and investigation, process improvement initiatives were highlighted and continuous improvement activities were undertaken. Successful implementation leads to improved results in these production processes. Two process improvements were done and this can be found starting from page 70.

The last objective was to develop a framework for optimal implementation of the principles of the Toyota model by for the tier 2 supplier. A framework for easy implementation of the Toyota way principles were put together as well as a step by step framework guideline if any principles were to be implemented for the first time. The author also went on to add an additional three principles to the framework. These Principles focus on activities, support from management and the involvement of people from the process. The framework created is not particular to the tier-two supplier, but instead to any organisation whom chooses to implement any of the Toyota way principles. This can be found starting on Page 95, Figure 0.1 , Figure 0.2 and Appendix J.

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APPENDICES

Appendix A: Letter of Permission



Dear Sir/Madam

I, Prenisha Govender, am a student at Durban University of Technology studying for my Master of Engineering in Industrial Engineering. I am conducting a research on the topic “Comparative analysis of the implementation of Toyota Production Systems by benchmarking an SME to a tier-one supplier”.

The main purpose of the study is to obtain a better understanding of how manufacturing industries perceive Toyota Production Systems (TPS) and to possibly define the missing gaps in which TPS is only successful in Japanese based companies as compared to SMEs. With this information, recommendations can be made to improve the implementation of TPS in SMEs and possibly aid in developing a framework for optimal TPS Implementation in SMEs.

You have been selected to be a part of the interview/survey process. Your experience and opinions on the implementation of Toyota Production systems implementations will be greatly valued towards this research. Please note that should you wish to go under anonymous should you feel uncomfortable in disclosing your feedback, it is acceptable.

I will be very grateful to get a positive response from you.

Yours sincerely

Prenisha Govender

Email: 21509155@dut4life.ac.za

Phone: 076280817

Appendix B: Permission letter from Toyota



02 March 2022

Durban University of Technology
S4, Steve Biko Campus,
70 Chris Ntuli Rd
Musgrave, Berea

Dear Sir / Madam,

Re: Permission Letter to conduct research at Toyota Boshoku South Africa

This letter grants Miss **Prenisha Govender**, ID Number **970324 0336 08 1**, Student number **21509155** employee at Toyota Boshoku South Africa, permission to conduct her research project entitled **Comparative analysis of the implementation of Toyota Production Systems: Benchmarking an SME to a tier one supplier for the qualification : MNIND1 Master of engineering : Industrial**

Permission is granted based on the following conditions:

1. That no proprietary information is divulged
2. Research publication is subject to Toyota Boshoku South Africa's written permission
3. The research paper is submitted to Toyota Boshoku for approval, prior to submission

Should any of the above not be adhered to, permission will be withdrawn and all Toyota Boshoku material and references, including processes must be removed from the research.


Yours faithfully

Toyota Boshoku South Africa (Pty) Ltd

Approved


Gregory Ownhouse
Section Manager – Production Engineering

Accepted


Prenisha Govender
Student/TBSA Employee



Reg No 2005/017111/07 VAT Reg 4400221889
1 Beechgate Crescent, Southgate Business Park, Moss Kolnik Drive, Umbogintwini, 4120
P O Box 1000, Amanzimtoti, 4125 TEL: +27-31-949-4000 FAX: +27-31-949-4100
President: S Yamanouchi (Public Officer); Directors: T Yabushita, Chairman; M Fukamoto

Appendix C: Permission letter from Aeroklas Duys



LETTER OF INFORMATION

Title of the Research Study: Comparative analysis of the implementation of Toyota Production Systems between a tier one and tier two supplier

Principal Investigator/s/researcher: Prenisha Govender, Master of engineering student, DURBAN UNIVERSITY OF TECHNOLOGY

Co-Investigator/s/supervisor/s: Mr Mendon Dewa, DURBAN UNIVERSITY OF TECHNOLOGY

Brief Introduction and Purpose of the Study:

Good Day

My name is Prenisha Govender and I am a student at the DURBAN UNIVERSITY OF TECHNOLOGY studying for my Master of Engineering in Industrial Engineering. I am conducting a research on the topic "Comparative analysis of the implementation of Toyota Production Systems by benchmarking an SME to a tier one supplier".

You are being invited to consider participating in a study that involves undertaking primary research. The aim and purpose of this research is to obtain a better understanding of the manufacturing industries perceive Toyota Production Systems (TPS) and to possibly define the missing gaps in which TPS is only successful in Japanese based companies as compared to SMEs. With this information, recommendations can be made to improve the implementation of TPS in SMEs and possibly aid in developing a framework for optimal TPS Implementation in SMEs.

The research objectives are as follows:

1. To identify the current pillars of the Toyota Production System used by a Japanese cultured company and an SME
2. To investigate the strengths and weaknesses of the current Toyota Production System in a Japanese cultured company and an SME.
3. To develop a framework for optimal Toyota Production System implementation by SMEs.

The completion of interviews should not take longer than 6 minutes. If you happen to have any questions regarding the completion of the survey, please contact the researcher, Prenisha Govender on 0716280817 or email me on : 215019155@dut4life.ac.za

Risks or Discomforts to the Participant: Please note that there are no foreseeable risks or discomforts to participants.

Explain to the participant the reasons he/she may be withdraw from the Study: Please note that that there will be no adverse consequences for the participant should they choose to withdraw.

20 September 2022

Benefits: This will assist us in developing a framework in which we can ensure the Implementation of Toy Production Systems (TPS) is as successfully implemented in SMEs as compared to Japanese based companies.

Remuneration: Please note that there will be no remuneration for the participants.

Duration: Interviews will be conducted by myself on the research participants only and will take place on of the SME and Japanese based company. Due to the production at the plant and the limited time available the participants, interviews will be kept short as possible. Interviews will take approximately 15min each individual and surveys between 6-7min.

Costs of the Study: The participants will not be compensated for any data costs incurred from participation in the study

Confidentiality: Anonymity and confidentiality will be maintained, the information collected from study will be stored in a safe location and will not be accessible to unauthorized persons. All surveys interviews will be stored for a duration of five years. It will also be stored in an encrypted digital form. All data collected will be stored on paper at the library. After a duration of five years, it will then be removed and stored at the department of Industrial Engineering.

Results: Results will be summarized and reported in the dissertation for the title above. Results and overview of the survey results in the form of the completed and approved dissertation will be

Research-related Injury: No research-related injury is anticipated from participating in the study should there be a research-related injury or adverse reaction following participating in an interview research, there will be no compensation.

Storage of all electronic and hard copies including tape recordings: No tape recordings or any electronic will be used during this process.

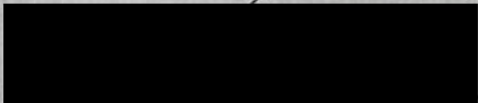
Persons to contact in the Event of Any Problems or Queries: Should you have any concerns or questions or you wish to lodge a complaint regarding your involvement in the research study, please contact the Research Ethics Sub-Committee Coordinator at DURBAN UNIVERSITY OF TECHNOLOGY: Ms I. dianais@Durban University of Technology.co.za

Arenoklas Duys

Name of Company

04/10/2022

Date


Operations Manager / PRODUCTION MANAGER

Researcher - Prenisha Govender(21509155)

20 September 2022

Appendix D: Ethics Approval letter



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Barwin Court
Gate 1, Steve Biko Campus
Durban University of Technology
P O Box 1334, Durban, South Africa, 4001
Tel: 031 373 2375
Email: lvishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics
www.dut.ac.za

3 November 2022

Ms P Govender
12 Scorpio Street
Woodhurst
Chatsworth
4092

Dear Ms Govender

Comparative analysis of the implementation of Toyota Production Systems between a tier one and tier two supplier
Ethics Clearance Number: IREC 171/22

The DUT-Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of your data collection tool.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the DUT-IREC acknowledges receipt of your gatekeeper permission letters.

Please note that **FULL APPROVAL** is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

Yours Sincerely


Professor J K Adam
Chairperson: DUT-IREC

Appendix E: Letter of Information



Date: 04 September 2022

Title of the Research Study: Comparative analysis of the implementation of Toyota Production System between a tier-one and tier-two supplier

Principal Investigator/s/researcher/s and affiliation: Prenisha Govender, Master of Engineering student, DURBAN UNIVERSITY OF TECHNOLOGY

Supervisor: Dr Mendon Dewa, DURBAN UNIVERSITY OF TECHNOLOGY

Dear Participant,

You are being invited to consider participating in a study that involves undertaking primary research. The aim and purpose of this research is to obtain a better understanding of the manufacturing industries perceive Toyota Production Systems (TPS) and to possibly define the missing gaps in which TPS is only successful in Japanese based companies as compared to SMEs. With this information, recommendations can be made to improve the implementation of TPS in SMEs and possibly aid in developing a framework for optimal TPS Implementation in SMEs.

The research objectives are as follows:

1. To identify the current pillars of the Toyota Production System used by a Tier-one and tier-two supplier

2. To investigate the strengths and weaknesses of the current Toyota Production System in a tier-one and tier-two supplier.
3. To develop a framework for optimal Toyota Production System implementation by SMEs.

Conflict of interests:

There is no conflict of interests for the researcher or supervisor.

Risks or Discomforts to the Participant:

Please note that there are no foreseeable risks or discomforts to participants.

Benefits:

This will assist us in developing a framework in which we can ensure the Implementation of Toyota Production Systems (TPS) is as successfully implemented in SMEs as compared to Japanese based companies.

Reason/s Why the Participant May Be Withdrawn from the Study:

Please note that that there will be no adverse consequences for the participant should they choose to withdraw.

Remuneration:

Please note that there will be no remuneration for the participants.

Costs of the Study:

The participants will not be compensated for any data costs incurred from participating in the study.

Duration

Interviews will be conducted by myself on the research participants only and will take place on site of the SME and Japanese based company. Due to the production at the plant and the limited time available of the participants, interviews will be kept short as possible. Interviews will take approximately 15min each per individual and surveys between 6-7min.

Anonymity and Confidentiality:

Anonymity and confidentiality will be maintained, the information collected from the study will be stored in a safe location and will not be accessible to unauthorized persons. All surveys and interviews will be stored for a duration of five years. It will also be stored in an encrypted digital format. All data collected will be stored on paper at the library. After a duration of five years, it will then be removed and stored at the department of Industrial Engineering.

Research-related Injury:

No research-related injury is anticipated from participating in the study and should there be a research-related injury or adverse reaction following participating in an interview for research, there will be no compensation.

Notification of research findings:

Each participant has the right to be informed of the findings of the study. The thesis will be available in the DURBAN UNIVERSITY OF TECHNOLOGY library. Additionally, the participants will receive the summarised findings of the study through the company.

Research Ethics Approval:

This study has been ethically reviewed and approved by the DURBAN UNIVERSITY OF TECHNOLOGY Research Ethics Sub-Committee (REC) (Approval Number: to insert).

Person to Contact in the Event of Any Concerns or Queries:

Should you have any concerns or questions or you wish to lodge a complaint regarding your involvement in the research study, please contact the Research Ethics Sub-Committee Coordinator at DURBAN UNIVERSITY OF TECHNOLOGY: on dianais@dut.ac.za

If you have any questions, or concerns about the study, please do not hesitate to ask me on the details below:

Prenisha Govender

Email: 21509155@dut4life.ac.za; Phone: 071628081

Appendix F: Covering Letter to Respondents



Dear Participants

I, Prenisha Govender, am a student at DURBAN UNIVERSITY OF TECHNOLOGY studying for my Master of Engineering in Industrial Engineering. I am conducting a research on the topic “Comparative analysis of the implementation of Toyota Production System between a tier-one and tier-two supplier “.

The main purpose of the study is to obtain a better understanding of how manufacturing industries perceive Toyota Production Systems (TPS) and to possibly define the missing gaps in which TPS is only successful in Japanese based companies as compared to SMEs. With this information, recommendations can be made to improve the implementation of TPS in SMEs and possibly aid in developing a framework for SMEs to assist in the implementation of TPS.

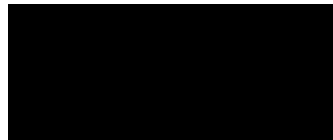
The completion of interviews should not take longer than 15 minutes and the surveys between 6-7mins. The purpose of the interviews is to gather ongoing interactions with the employees on site to gain further clarity and insight to the implementation of Toyota Production Systems in SMEs. Personal interactions with participants in this research will assist in gaining better insight in the shortfalls of TPS principles being implemented and successfully sustained. Answers from the survey will be quantified and shown graphically. Answers from the interviews will assist in understanding the strengths and weaknesses of implementing TPS in each of these environments. Feedback from both the SME and the Japanese based company will be used in developing a framework for the optimal implementation of TPS in SMEs.

Please note that if you wish to go under anonymous should they you feel uncomfortable in disclosing your feedback, it is acceptable. There is also no incentive in partaking in this research.

If you happen to have any questions regarding the completion of the survey, please contact the researcher, Prenisha Govender on 0716280817 or email me on : 215019155@dut4life.ac.za .Thank you for your participation and for taking the time to assist me with my research.

Yours sincerely,

Research's signature:

A solid black rectangular box redacting the signature of the researcher.

Date: 04/09/2022

Appendix G: Consent Form for Applicants

I, _____ (full name of the participant), hereby confirm that I:

1. Have been informed by the researcher, (Prenisha Govender), about the nature, conduct, benefits and risks of this study.
2. Have also received, read and understood the Letter of Information regarding the study.
3. Have been informed that if I feel uncomfortable in disclosing any feedback, I can go under anonymity as my personal information and demographic information does not contribute to the basis of this research.
4. Have also been informed that the results of the study, including personal details required by the study will be anonymously processed into a study report.
5. Have been informed that there is no incentive in part taking in this research interview or survey.
6. Agree that the data collected during this study can be processed in a computerised system by the researcher.
7. Am aware and understand that I may, at any stage, without prejudice, withdraw my consent and participation in the study. Where I have had questions regarding the study, these have been answered by the researcher to my satisfaction.
8. Understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Additional consent, where applicable

I hereby provide consent to:

- Audio-record my interview / focus group discussion YES / NO / NOT APPLICABLE
- Video-record my interview / focus group discussion YES / NO / NOT APPLICABLE

I declare that my participation in this study is entirely voluntary.

Full Name of Participant	Date	Signature
---------------------------------	-------------	------------------

Full Name of Supervisor	Date	Signature
--------------------------------	-------------	------------------

Appendix H: Questionnaire

SECTION A: DEMOGRAPHICS

Name: _____

Age: _____

Occupation: _____

Duration of employment: _____

SME or Japanese based company _____

SECTION B: QUESTIONNAIRE

1. Do you currently work at a Durban based automotive manufacturer?
Yes / No
2. Are you in the: Engineering department/ Maintenance department / Involved in production (directly – team members) / Involved in production (TL/GL)

The following questions aim to investigate the strengths and weaknesses of Toyota Production Systems and its successful implementation in different environments. Please select from the options: strongly agree, agree, neutral, disagree or strongly disagree.

			Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1		Toyota Production Systems (TPS) can improve profitability, process, and quality in a business.					
2	P1	My company's vision and mission coincides with the best interest of the customer.					
3	P1	Management bases their decisions on long term philosophy of the business.					
4	P2	The company has a continuous improvement culture.					
5	P2	The company creates a continuous process flow to bring problems to the surface.					
6	P2	Improvements are done on a continuous basis.					
7	P3	The company uses a Pull system when supplying the customer and to avoid overproduction.					
8	P3	The pull system methodology works for the company (if being used)					
9	P4	The 7 types of waste are known and are made known by the company's way of improving.					
10	P4	There are ongoing activities that are in place to reduce the wastes from the process.					
	P5	The company has techniques In place to ensure that quality is at its best and delivered to the customer and right the first time.					

P5	There are alert systems in the manufacturing process to identify defects at the same time.					
P6	Standardised work is part of daily routine.					
P6	There are measure in place for standardised work					
P7	There are visual controls at the process to ensure that there is no deviation from the process.					
P8	The company has cutting edge technology to improve processes.					
P8	The company is currently investigating further technology to improve the business processes.					
P9	The company has training programs in place to grow leaders.					
P9	Training is done often for the employees of the company to grow their skills.					
P10	There are activities in place that consist of cross functional teams.					
P10	People are developed to follow the company's philosophy.					
P11	The company assists in improving suppliers and partners.					
P12	Genchi Genbutsu is a term that is familiar in and around the company.					
P13	Decisions are made after carefully considering all					

		options and is implemented rapidly.					
	P14	The company is a learning organisation as reflection and continuous improvement is carried out.					

Appendix I: Ethics certificate



Zertifikat Certificat

Certificado Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

Prenisha Govender

a complété avec succès - has successfully completed

Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/04/03
CID: FRESjDwYL



Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

APPROVED BY
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[REV : 20220217]

Appendix J: 14 TPS principles guideline framework

14 Implementation step by step guideline framework		
Principle	Description	How to implement
Principle 1	Philosophy	1. Knowledge and background knowledge should be shared with top management and then thereafter to lower management for knowledge sharing.
Principle 2	Overall management participation and direction of organization	1. Higher management to initiate new quality/safety/productivity initiatives which will overall improve the business. 2. Weekly production meetings for process management to show continuous improvement items/activities. 3. Executive level managers to manage key performance indicators of production processes.
Principle 3	Process management of teams	1. Production line management to drive continuous improvement strategies for betterment of the future. 2. Production line leaders to start activities and guide production members for continuous improvement.
Principle 4	One piece flow	1. Knowledge to be shared of the techniques on one piece flow implementation. 2. Process study to be completed with a multifunctional team. 3. Process suggestions and line balancing to be done. 4. Simulation trials to be conducted and scores to be tabulated for improvement analysis. 5. Full implementation and standardization (work instructions, training etc)
Principle 5	Use pull system	1. Knowledge to be shared of the techniques on one piece flow implementation. 2. Process study to be completed with a multifunctional team. 3. Process suggestions and line balancing to be done. 4. Simulation trials to be conducted and scores to be tabulated for improvement analysis. 5. Full implementation and standardization (work instructions, training etc)
Principle 6	Heijunka	1. Study current process of different variants of products. 2. Ensure different variants and their processes are studied indepth. 3. Rebalance variants to ensure variants that take longer are inbetween variants with a shorter manufacturing/lead time.
Principle 7	Jidoka	1. Members at quality gates should be highly skilled at quality inspection. 2. Automated equipment should be implemented and installed to detect abnormally any defect or deviation from process.
Principle 8	Standardized work	1. Current processes to be studied. 2. Abnormal and normal process detection. 3. Abnormality removal elements from process. 4. Establish process. 5. Create new work instruction. 6. Train employees on new process standard.
Principle 9	Visual management	1. Process standard to be established correctly without abnormal activities. 2. Work instructions to be created. 3. Work instructions to be put up at processes.
Principle 10	Use of reliable and proven technology	1. Processes to be stabilized and standardized. 2. Processes to run at a 90% efficiency rating. 3. Technological scope to be drawn. 4. Potential suppliers to be contacted. 5. Concept to be shared with manufacturing department - department technological advancement to be implemented in.
Principle 11	Grow leaders	1. All Leaders from production processes should be knowledgeable on all 14 principles. 2. Annual courses to run for all manufacturing leaders, engineers, continuous improvement personnel for knowledge sharing. 3. Manufacturing leaders to then share knowledge further down to production floor members.
Principle 12	Develop exceptional people and teams	1. Development of individuals by training on productivity, quality and delivery to enhance customer satisfaction. 2. Mentorship programs to be initiated by management for growth of individual purposes.
Principle 13	Respect extended network of partners and suppliers	1. Annual/ bi-annual audits to be done to all suppliers. 2. Improvement activities to be started amongst suppliers for process improvement.
Principle 14	Involvement of people at the process	1. Involvement of members at the process for all activities. 2. Weekly meeting feedback on company direction and plan. 3. Bi - annually feedback on performance and company/production status.
Principle 15	Genchi genbutsu	1. Knowledge to shared on this terminology is first required. 2. Management to host or schedule weekly Genchi genbustu activities to show initiative for process improvement to managers on a lower level. 3. Line management to then carry activity out and show weekly improvements to management.
Principle 16	Decisions by slow consensus	1. Decisions should be properly investigated with relevant departments involved together. 2. Relevant departments to come together and agree on one decision. 3. Decisions to be implemented and carried out. 4. Implementation staus to be tracked and evaluated.
Principle 17	Kaizen, becoming a learning organization	1. Kaizen knowledge to be shared with all members of the organization. 2. Kaizen improvement programs to be implemented and driven by higher management.