5th African International Conference on Industrial Engineering and Operations Management, Johannesburg/Pretoria, South Africa, April 23 - 25, 2024
Publisher: IEOM Society International, USA
Published: April 23, 2024 DOI: 10.46254/AF05.20240006

Application of Lean Principles to a Waxing Process in Automotive Manufacturing

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Abstract

This project focuses on improving the waxing process in the automotive industry by the application of lean principles. The motivation behind this project is to improve the delivery time and coat in the waxing company. The project was done at the on-premises waxing system of the automotive industry. Insufficient waxing process was identified as the primary cause during the analysis phase of the project. A quantitative approach was used, and the tools used in this project were time studies, interviews, Ishikawa diagrams, and Pareto analysis. The capacity is insufficient to fulfill daily demand during normal working hours, causing production to continue after being halted due to unanticipated events. The improved procedure was offered, and other options were created by combining feasible enhancements, such as bringing the waxing process in-house. This will reduce travel time between two facilities from OEM to offsite and to the harbour. The final produced design was chosen to wax the units in-house instead of using an outside vendor.

Keywords:
Lean Manufacturing, Process optimization, industrial engineering

1. Introduction

This paper investigates ways of improving the underbody wax's delivery time and quality for all exported vehicles at the XYZ Automotive company using lean manufacturing (LM) tools. The company manufactures different models such as commercial vehicles, vans & buses, and luxury passenger cars but this study will only focus on the exported passenger cars. The goal of the company is to produce high-quality vehicles at a low cost with less input. There is high demand for exported passenger cars from South Africa (SA) to customers around the world since they also need the underbody to be waxed at a local supplier, which protects the car from corrosion because of the sea weather conditions during the shipment (Zide 2012). This turns out to be very costly for the organization and since there is a high demand for these passenger cars, this has a big impact on the XYZ company's profit margin.

An international automotive Original Equipment Manufacturer (OEM), which is in the Eastern Cape province, manufactures a variety of left & right car models such as petrol, diesel and hybrid cars. The organisation got different departments which are Bodyshop, Paint shop & Assembly that works together to produce the final product.

The assembly department is the last area where the units will go through before it goes to the customer. 97% produced by this OEM is export and only 3% is for South Africa, this shows that there is a huge demand for the exported units since there is extra work that needs to be done on the units before they get shipped. The extra process that needs to be done is underbody waxing of the units to prevent them from corrosion during the shipment process while they are still on a vessel. The strategy of improving the underbody wax process to make it more efficient and effective, which will reduce the delivery time and quality.

2. Literature Review

2.1 Lean manufacturing

Lean Manufacturing is based on the Toyota Production system developed by Toyota which focuses on eliminating waste, reducing inventory, improving throughput, and encouraging employees to bring attention to problems and suggest improvements to fix them (Womack et. al.1991). Lean manufacturing is a production system that focuses on reducing waste, creating customer value, and seeking continuous process improvement (Phuong et. Al 2023). That was pioneered by the Japanese automotive Toyota in the 1950s, LM has become the best adaptable manufacturing practice by a lot of automotive industries. Even though LM was was developed by the automotive industry and adopted by other automotive industries that do not mean it cannot be applied in other different industrial sectors. Based on the literature reviewed it shows that you can apply lean manufacturing anywhere where there is waste reduction involved.

2.2 Plan-Do-Check-Act PDCA

The PDCA (Plan, Do, Check, and Act) method, which was created in Japan in 1950 by P.HINES, is at the heart of the continuous improvement philosophy. Through this continuous cycle and quality control, the PDCA cycle has its own advantages that make many parties use it for continuous product quality improvement (Jiang, 2021). The following is the objective of each piece that makes up this -cycle (Figure 1): PLAN DO CHECK ACT

- Plan: gather and analyse data, ideas, and proposals to determine the optimal improvement strategy.
- Do: carry out the chosen strategy.
- Check: gather data and confirm that the desired outcomes were achieved;
- Action: keep the implemented plan in place and, if required, take corrective action.

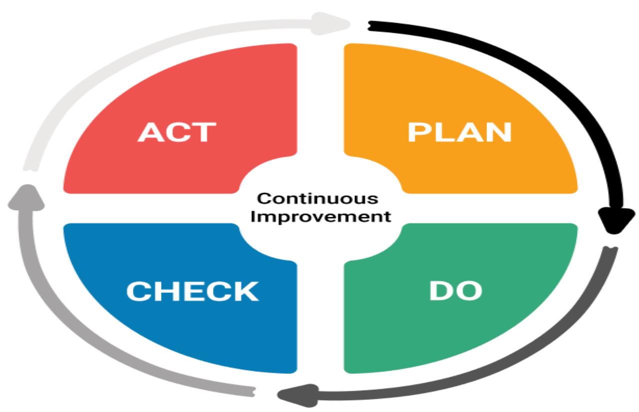

Figure 1. PDCA cycle

Lean production

The creation of Lean Production is rooted in the production system of a Japanese automotive company called Toyota Motor Corporation and it was introduced to the world of the industry as a new way of making things in the book “the machine that changes the World” by Womack, Jones, and Roos (1990). Furthermore, it still requires less than half the inventory, resulting in fewer faults, greater production levels, and increased product variety, thereby converting a system "lean." The advantages of small-scale production and mass production are integrated into this set of lean production while avoiding the high costs of the first and the rigidity of the second. Lean production is the elimination of waste with the goal that all steps in a process add value from the customer’s perspective [Soderborg, 2008].

Lean principles

Principles of Lean Manufacturing This idea, according to Womack and Jones (1991) is the "antidote to waste," giving means to clarify what is meant by value, begin the value of creating actions in the best sequence, and continue these activities in an effective manner without interruption, whenever someone demands it. As a result, the writers recognized the following principles as being related to this philosophy: value, value chain, flow, pull (pulling), and perfection (Figure 2).

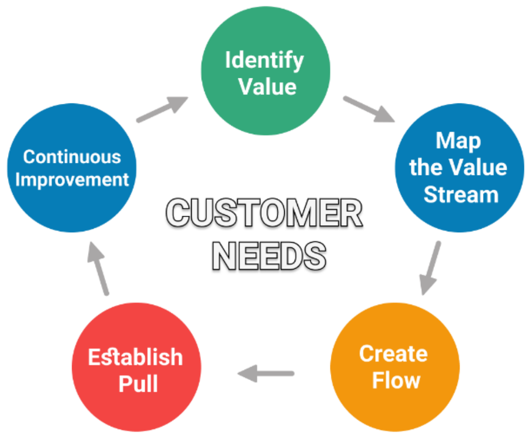

Figure 2. Five lean principles

Application of lean manufacturing

Lean manufacturing in Food and Beverage Industries

According to Borges et. al. (2015), LM principles were applied in two Portuguese companies of the Food and Beverage Industries where there were conducting a single minute exchange die (SMED) analysis to improve the change-over-time on the tool and other LM tool that was used was a 5s method, even though the benefits of this method were not easy to measure but the advantage that was identified was less risk of work accidents, better working condition and optimized storage space etc.

Lean six sigma tools in the ophthalmology clinic

Lean Six Sigma is one of the LM tools, which was applied in ophthalmology clinics to reduce patient waiting time and increasing service capacity due to the increasing number of patients it became complicated to manage patients and the limitation of healthcare resources resulted in prolonged waiting times, decreased quality of service and reduced patient satisfaction.

Theory of constraints

Boyd and Gupta (2004) set forth TOC as a theory through a clear identification of the underlying construct "throughput orientation" in addition to its three dimensions: Mindset, Measures and Methodology. Gürses (2007) have examined the theory of constraints, and he applied this theory in Project Management which is the one of the biggest application fields. The theory of constraints was applied to the approach of Critical Chain Project Management and the benefits provided were specified at the end. Yükçü and Yüksel (2015) have applied the theory of constraints to hospitals which are one of the production and service businesses.
Goldratt approaches constraints and bottlenecks of a business as an opportunity and since each production activity is connected to the following process, he considers the production process of a business as a chain and the present constraints as the weakest link of the chain (Karakoc and Eser 2021).

2.3 Six sigma

Six sigma has been considered as a philosophy that employs a well-structured continuous improvement methodology to reduce process variability and drive out waste within the business processes using statistical tools and techniques (Ban˜uelas and Antony 2002). Motorola was one of the companies that was successful in adopting the Six-sigma method in the 1980s, in an effort to increase the level of quality by reducing variability in manufacturing operations in a continuous and consistent manner (Olanrewaju et al., 2019). Lean is an approach for improving processes so that products and services are delivered better, faster, and at a reduced cost. It's a means to specify the value, line up value-creating tasks in the optimum sequence, do those activities without interruption anytime someone asks, and accomplish them more and more effectively, according to Womack and Jones (1990). Lean and Six Sigma are two widely acknowledged business process improvement strategies available to organisations today for achieving dramatic results in cost, quality, and time by focusing on process performance (Kumar et al.2006).In a nutshell, lean thinking is lean because it allows you to do more with less—less human effort, less human equipment, less time, and less space—while getting closer to giving clients exactly what they want. Six Sigma is a data-driven process improvement methodology for minimizing process variation and errors and achieving consistent and predictable process results. Figure 3, is the Lean Six Sigma principles of approaching at problem, are as follow.

Figure 3. Lean Six sigma principles (Kumar et al.2006)

2.4 Value stream mapping

Procurement Value Stream Mapping Value stream mapping is a collection of all actions that produce added value as well as non-added value activities that are required to complete the Purchase Request process and turn it into a Purchase Order. This activity is an element of the procurement process, which also comprises the procurement flow. Value Stream Mapping is a procedure model, that complements classical Value Stream Mapping with specific quality related elements to systematically visualize, analyze and improve quality issues within a process chain by Haefner et al. (2014).

VSM is an iterative process which usually includes selecting the product family, identifying the CSM, analysing waste and mapping the future state (Chen, Li, and Shady2010; Jiménez et al.2012; Lacerda, Xambre, and Alvelos 2016). The process has three critical elements, including the current state VSM which shows how both materials and information flow in the current system, the identification of waste (e.g. Waiting, inventory, transportation, and defects) and the future state VSM which shows the ideal production system (Shou et. al, 2017). Taking steps in terms of the value stream entails working on a big scale and improving the overall flow as opposed to piecemeal optimization. This results in a language that is routinely used in the purchase of goods, allowing for more mature judgments to be made to improve the value stream. Value Stream Mapping can help a company find the right turning point. The following are the two main steps in VSM mapping:

1. Creating a Present State Map to map the current procurement conditions so that any waste can be identified. Map of the Current Situation Before we make any modifications, we must first examine the present process flow.

2. The creation of the Future State Map as a recommended design for improving the current state map is a description of the process and information once the improvement has been completed.

3. Performance measures

The waxed unit throughput, the number of overtime hours worked to satisfy demand, and the number of units delayed for export. This section will go over the three key performance indicators for this project. Financial analysis, precise delivery schedules for each delivery route, and supply chain management are examples of measures that are outside the scope of this project.

Research Methodology

The positivistic philosophy would be the best fit for the research because it relies on quantitative data, which is thought to be more dependable than qualitative data. Quantitative research is frequently believed to be more scientific in its methodology and thus more reliable than qualitative research. Furthermore, this philosophy gives objective data that may be used by the researcher to develop scientific assertions. When it comes to analyzing employee engagement and its impact on productivity, positivism adheres to a well-defined format during studies and dialogues.The project focuses on improving the system for waxing process and delivery time, a literature study was undertaken on the subject, on topics that developed from this project, and on other authors who have examined or addressed similar challenges during the literature phase. A quantitative approach was applied, and the tools used in this project are Time studies, interviews, Ishikawa diagrams, and Pareto analysis. Insight was gained through work experience and interviews. Using a mix of an Ishikawa diagram and Pareto analysis, the root cause was discovered. The capacity is insufficient to fulfil daily demand during normal working hours, causing production to continue after being halted due to unanticipated events**.**

3.Results and Discussion

The XYZ automotive manufactures cars and transports them to a waxing company for underbody waxing and the supplier will then transport the waxed units to the harbour . The underbody wax system consists of two processes: vehicle production & waxing and delivery unit to the harbour.

Underbody system

In figure 4 is the underbody waxing system that consist of two manufactures which are XYZ Automotive and waxing company. The OEM manufactures different types of units and distinguishes the non-wax unit from the wax units. All units are then transport to the waxing company where they will receive a waxing. Once all units are done then it is transported from the waxing company to the harbour upon the arrival of the vessel.

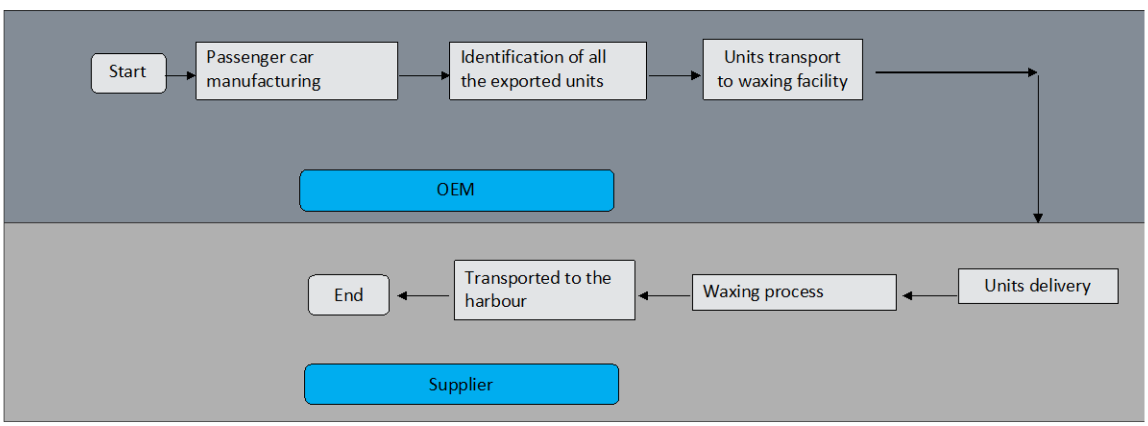

Figure 4. Underbody system

Waxing process

Figure 5 depicts the underbody wax process, which was constructed using data acquired using problem solving tools. The waxing company is responsible for collecting the cars from the XYZ company, wax them and transport to the harbour, the most important part is the underbody waxing where the unit will be aligned back-to-back and lifted up with the hoist in the waxing booth. Underbody covers will be removed and the unit will be waxed once it is done then the covers will be placed back, and the wax fault will be cleared and captured on the system.

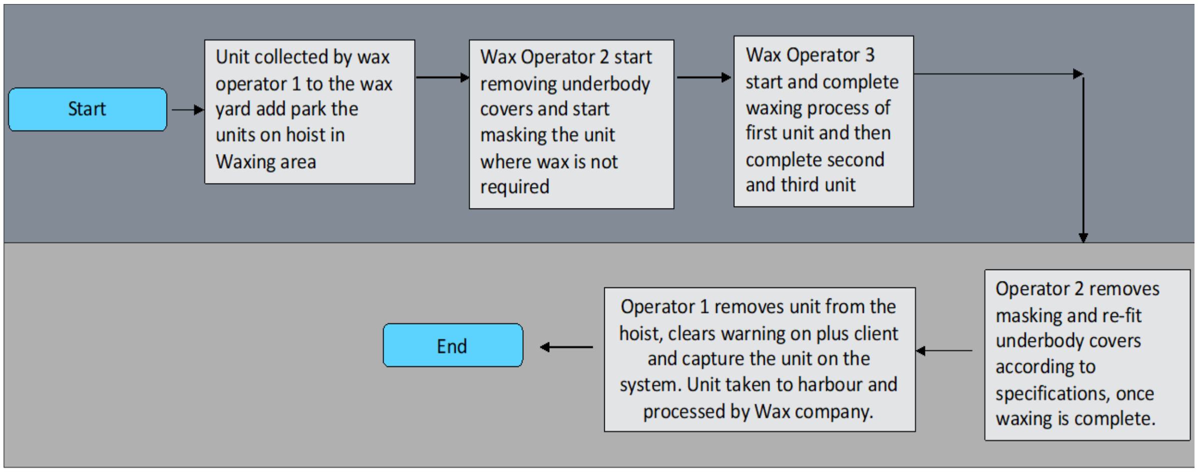

Figure 5. Underbody process

Delivery process

Figure 6, illustrate the transportation process of the units from the manufacturer through the waxing company until it ends up at the harbour. The cars are being transported with a truck that can carry a maximum number of 6 units per load.

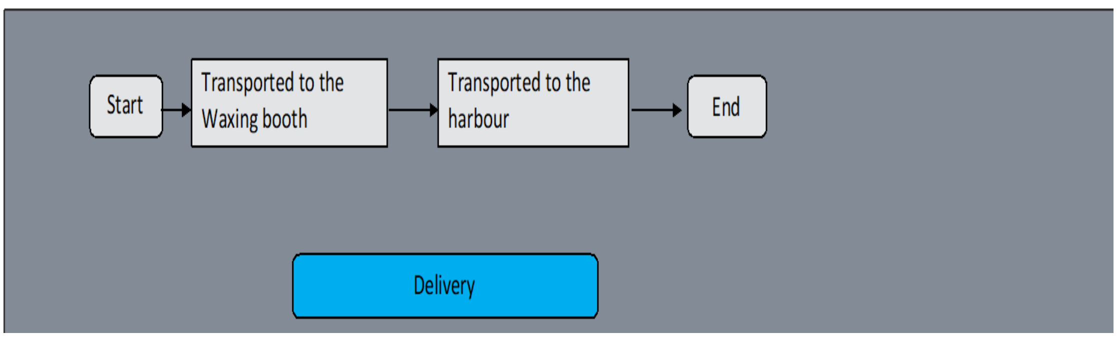

Figure 6. Delivery system

Current capacity state

Figure 7 is the illustration of the current state capacity of the underbody system, where the underbody waxing in orange colour is the bottleneck on the system by 60min.

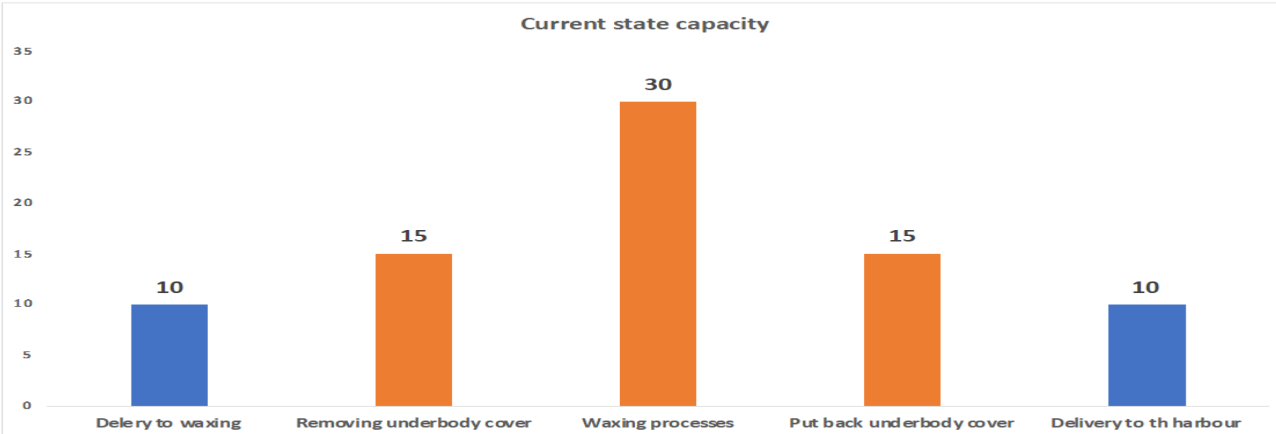

Figure 4. Current Capacity states

Current state for car delivery analysis

The historical data of the cars delivered at the harbour were obtained from the SAP system. Figure 8 depicts a weekly delivery of the cat at the harbour done by the waxing company, weekend is excluded on this data since they are being used as overtime to meet the customer demand. The weekly statistics shows that there is a delay in the car deliverers, this is not a good picture for the company because it will inquire more cost for delaying the vessel.
The target is 2250 units per week, but with this state it shows that the weekly average waxing company can delivery is 1716 units, with this trend it shows that at the end of the month waxing company won't be able to meet the customer demand, and that causes the a delay on the vessel.

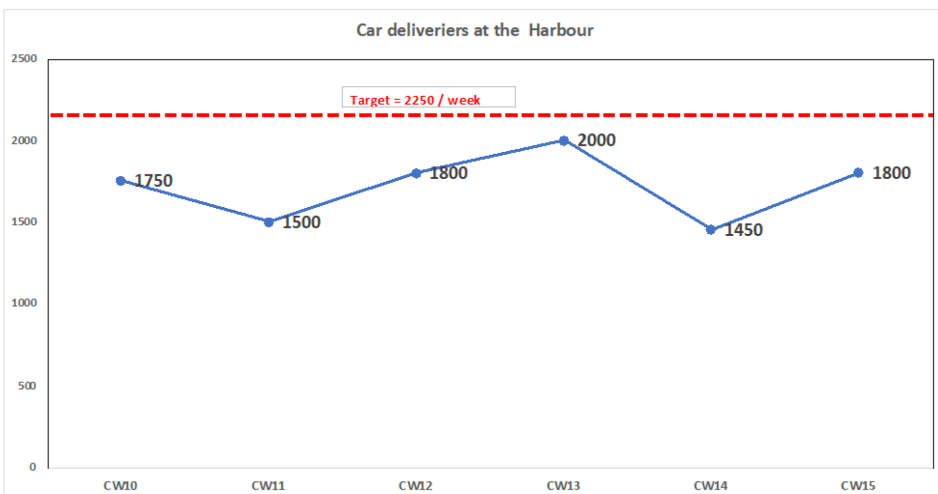

Figure 8. Car weekly delivery

Underbody waxing process per unit

Table 1, illustrate the underbody cycle time, the data was collected from the production through put reporting system. With this date is shows that the average cycle time is 55 min which is almost an hour just wax one unit. And with the delivery times on figure 12, which takes 10 min to transport the cars to the waxing company and another 10 min from the company to the harbour which adds up to 20 min delivery time per unit.
In summary the to process one unit from start to end it takes an approximately 80 min, that is a lot of time compared to the takt time.

Table 1. Underbody cycle time

Car	**Remove underbody cover(min/car)**	**Wax underbody (min/car)**	**Remove underbody cover(min/car)**	**Total processing time**
A	15	25	13	53
B	12,5	30	12	54,5
C	11	35	14	60
D	13	22	16	51

Problem Analysis

In-order to understand the causes of late deliveries and insufficient processing line a root cause analysis was performed on the current condition by combining a Pareto Chart and fish-bone diagram analyses. The Pareto diagram, as shown in Figure 9, directs attention to which parts of the process should be prioritized and Figure 10 is the cause and effect to understand the contributing factors on the delays. The most common source of concern was the system capacity, which would be addressed by the suggested adjustments.

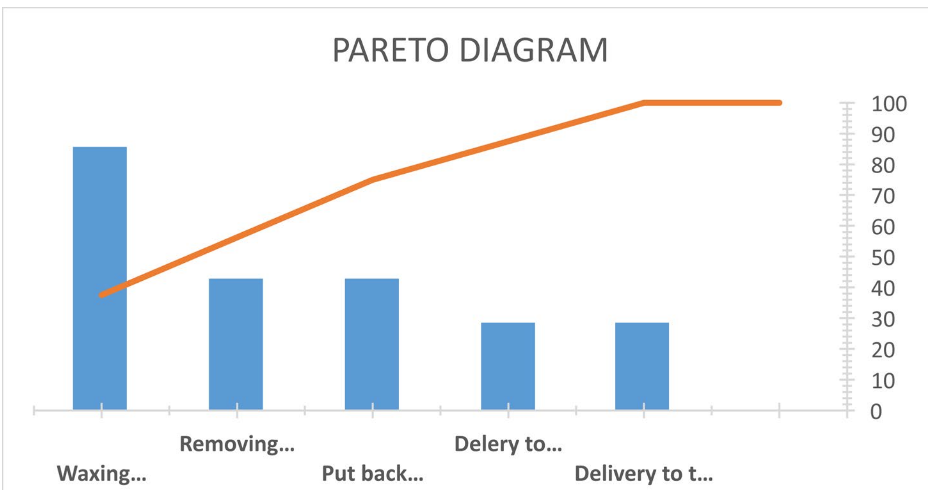

Figure 9. Pareto diagram of the waxing process

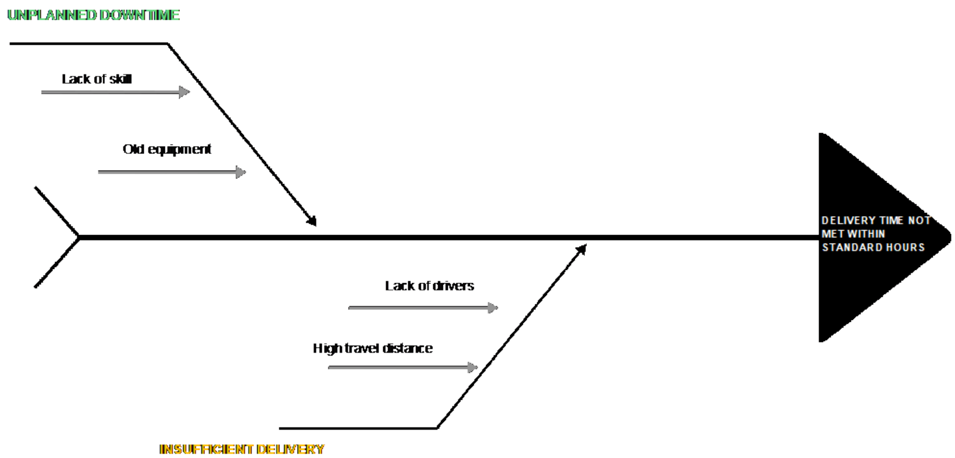

Figure 10. Cause and effect diagram

Unplanned downtime

Because the equipment is old and breaks down occur more frequently, unplanned downtime is another likely cause of the problem. The unplanned downtime is hidden by overtime, therefore this cause is not evident in the system.

Insufficient delivery

Due to the unplanned breakdown and the lack of skilled labor that cause the company to have late deliveries because they take too long to wax the unit. The double handling of transporting the car from one point to another is also a problem since the travelling distance is a bit longer.

Survey Data Presentation

Figure 11, is the percentage of the survey that was shared with the employees to complete in the period of three weeks, from the survey its shows that 80% of the problems stem from the waxing company and 20% from the OEM.

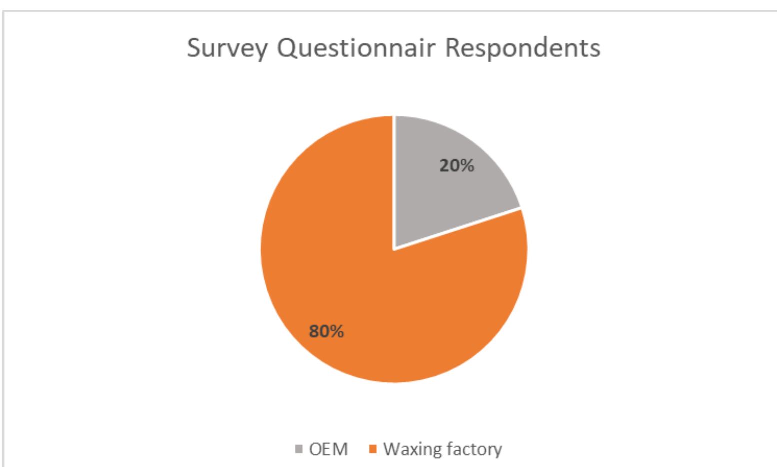

Figure 5. Percentage respondents

5. Conclusion and Recommendations

The waxing business has a hard time satisfying everyday demand during regular business hours. The primary goal of this project was to create a better underbody waxing procedure and give recommendations for which portions needed to be enhanced to fulfil the new system's requirements. The unit's delivery time is one of the areas that must be improved. By bringing the service in-house rather than using an outside vendor, the organisation would be more profitable.

Only after a solid understanding of the concepts of constraints and lean manufacturing could the system capacity be balanced. Following a review of the literature on the theory of constraints and lean manufacturing, many approaches to solving the problem were evaluated. After analysing all the options, it was determined to create a system that merged some of them to get the greatest result.

The final output included a proposal for which areas required improvement. A better waxing system was proposed created to cut down on time wasted during the waxing procedure.

A high-level implementation plan accompanied the newly designed waxing system. This technology can be used to establish a faster delivery time while also increasing capacity. The final system design simulation results were compared against historical data from both the proposed state and the current state. This comparison revealed a massive increase in system capacity, resulting in far more system capacity than the current system can handle. For the underbody waxing to process a backlog during working hours, the increased capacity also requires a far larger margin for mistake.

The final design and recommendations, as well as a high-level implementation plan, were given. The project's goal and objectives were met on schedule.

Following are some of the recommendations that can improve the effectiveness and efficiency:

- Build in-house facility that will eliminate double handling from the manufacture to the supplier, is the proposed improved layout if the process is being done in house without the external supplier.
- Improving underbody waxing process to minimize delivery times even further from 5 heads to 2 heads since there is no requirement for more drivers to drive the cars to the supplier offsite facilities.
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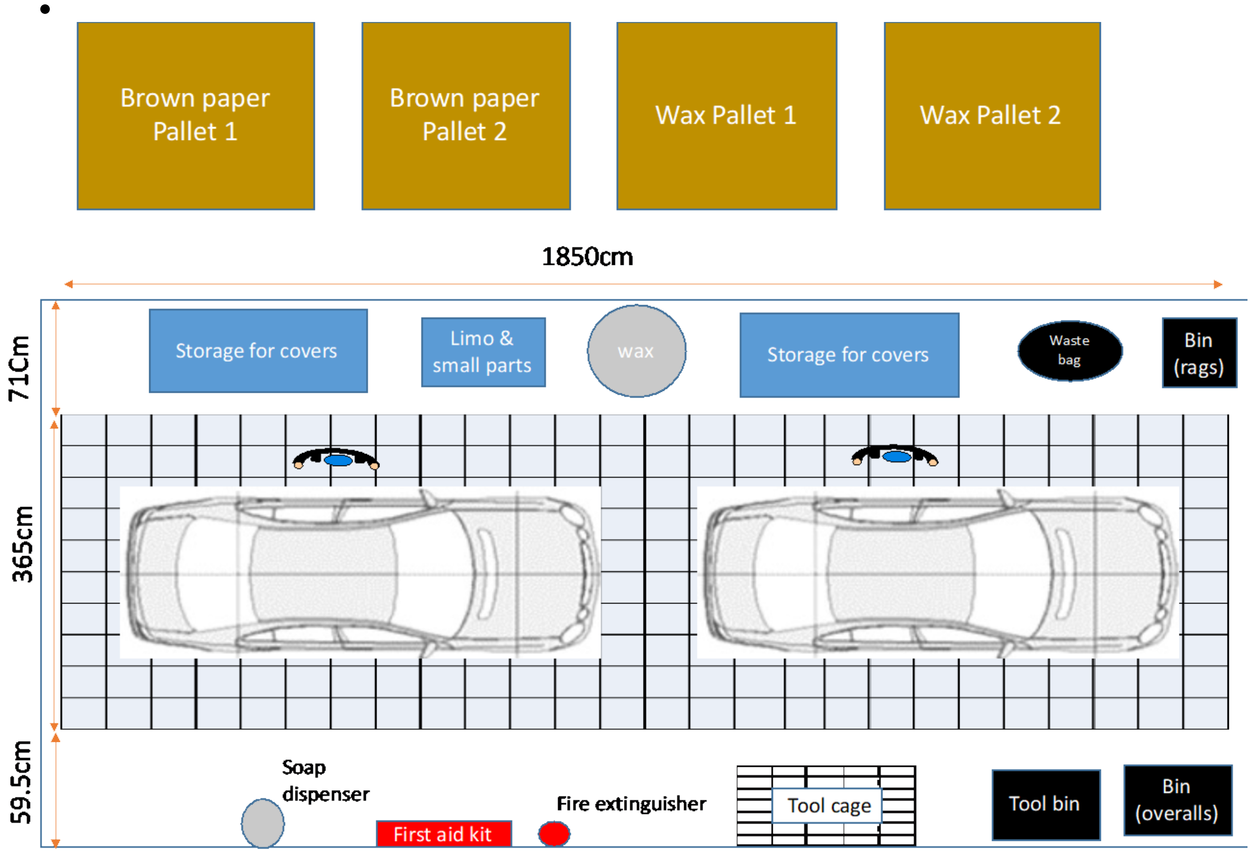

Figure 6. Proposed new layout.

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Biographies

Prof Kem Ramdass has worked as a work-study officer, industrial engineer, production/operations manager and skills development facilitator in the clothing, electronics, and textile industries between 1981 and 1999. He joined the academic profession in 1999 as a lecturer with Technikon South Africa. He later moved to UNISA'S Department of Business Management in 2006 lecturing in operations management. He is currently a Professor in the Department of Industrial Engineering based at Unisa, Florida Campus. He has a passion for quality and firmly believes that the application of quality management methodologies will highlight deficiencies and instigate the implementation of improvement strategies. He has applied continuous improvement methodologies from an industrial engineering, quality, and operations management perspective. He is a process, performance, and operations specialist with a driving passion for improving production, quality, and competitiveness. He has authored and presented approximately 50 journal and conference papers both nationally and internationally and is a peer reviewer for numerous publications. He has achieved Fellow member status at SAIIE and is a member of PICMET and IEEE. He is registered as Pr Tech Eng at ECSA and is appointed as a member of the Code of Practice Steering at ECSA.

Dr Humbulani Simon Phuluwa has worked as a process engineer, industrial engineer, industrial engineer consultant in the service and manufacturing between 2001 and 2010. He joined the academic profession in 2014 as a lecturer with Tshwane University of Technology. He later moved to UNISA'S Department of Industrial Engineering in 2006. He is currently a Senior Lecturer in the Department of Industrial Engineering based at Unisa, Florida Campus. He has a passion for quality and firmly believes that the application of quality management methodologies, advance manufacturing, and sustainable manufacturing. He has applied continuous improvement methodologies from an industrial engineering, quality, and business process engineering perspective. He is a process, performance, and operations specialist with a driving passion for improving production, quality, and competitiveness. He has authored and presented approximately 5 journal and 6 conference papers both nationally and internationally and is a peer reviewer for numerous publications.