# Optimizing Auto Repair Shop Layout and Processes for Enhanced Performance Through Lean Manufacturing Principles

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***Abstract***

*Optimizing auto repair shop layouts and processes is essential to enhancing operational performance and reducing inefficiencies. Lean manufacturing principles, originating from the Toyota Production System (TPS), provide a structured approach to eliminating waste, improving workflow, and maximizing value in various industries, including auto repair. This study explores how lean tools such as 5S, Kaizen, and Value Stream Mapping (VSM) can be applied to auto repair shops to streamline operations, reduce waiting times, and boost servicing capacity. By analyzing the continuous improvement process, this review highlights how effective shop layout design, combined with lean practices, leads to sustained growth in capacity and operational efficiency. A performance graph demonstrates a steady increase in servicing capacity, showing notable improvements between 2023 and 2024, with stable performance achieved through better resource allocation and process optimization. The study concludes that applying lean principles in auto repair shop layouts offers substantial benefits in terms of productivity, service quality, and customer satisfaction.*

***Keywords: Lean Manufacturing, Auto Repair Shop Optimization, Process Improvement, Waste Reduction, 5S Methodology***

## 1. Introduction

Auto repair shops play a crucial role in vehicle maintenance and repair services. However, due to inefficiencies in layout and process management, these facilities often struggle with reduced productivity, long customer waiting times, and increased operational costs. Implementing lean manufacturing principles is a proven approach to enhance operational efficiency, reduce waste, and improve service delivery. Lean principles, originating from the Toyota Production System (TPS), emphasize waste elimination, continuous improvement, and maximizing customer value (Womack and Jones, 1996). Morales, Jonathan & Rodriguez, Ramon (2020) discuss the application of lean manufacturing tools like 5S, Kaizen, and OEE to improve the production of automobile parts. They highlight the effectiveness of implementing process standardization, balancing workloads, and conducting time-loss analysis to streamline operations, reduce waste, and enhance productivity. Scanion Auto Repair Shop is divided into – five main areas which include Air-Conditioning System Repair unit, Transmission System Repair unit, Engine system repair unit, Auto Body Shop Repair and Auto Electrical System Repair unit. The current automobile repair plant layout and processes suffers from inefficiencies such as excessive movement of materials and personnel, underutilization of space, bottlenecks in workflow, and unnecessary waiting times, all of which contribute to increased operational costs and reduced productivity. These inefficiencies lead to extended repair times, higher labor costs, lower throughput, and decreased customer satisfaction. Despite efforts to streamline operations, the traditional approach to plant layout and repair processes often fails to fully eliminate waste, optimize resource utilization, or enhance workflow efficiency. Consequently, there is a need to explore and implement Lean Manufacturing principles tailored to the unique challenges of automobile repair plants. Lean Manufacturing, with its focus on waste reduction, continuous improvement, and value creation, offers a systematic approach to optimizing plant layout and processes. The problem, therefore, is the lack of an optimized plant layout and process flow that aligns with Lean Manufacturing principles, resulting in suboptimal performance. This research aims to address this issue by identifying inefficiencies, analyzing the current state of operations, and proposing an optimized layout and process flow that enhances overall performance, reduces waste, and improves customer satisfaction

## 2. Lean Manufacturing Overview

Lean manufacturing is a systematic approach aimed at minimizing waste without sacrificing productivity. Waste in lean, often referred to as "Muda," comes in several forms: overproduction, waiting, excess inventory, unnecessary movement, over-processing, defects, and underutilized talent (Ohno, 1988). The 5S methodology, Kaizen, Kanban, and Value Stream Mapping (VSM) are some of the core lean tools applied in various industries to improve efficiency and optimize layouts. Studies show that applying lean manufacturing to service industries, such as auto repair shops, can result in substantial performance gains (Abdulmalek and Rajgopal, 2007). These principles focus on reducing non-value-adding activities and streamlining operations, which align closely with the needs of auto repair businesses.

### 2.1 Challenges in Traditional Auto Repair Shops

Traditional auto repair shops face several challenges, such as: Disorganized Layout: Poorly organized workspaces lead to inefficiencies in tool movement, part retrieval, and communication between mechanics (Chen et al., 2010). High Lead Times: Waiting for parts, tools, and instructions can significantly increase the lead time, reducing customer satisfaction. Underutilization of Mechanics' Skills: Repair shops may assign high-skill mechanics to tasks that do not fully utilize their expertise, leading to inefficiencies and bottlenecks in the repair process (Sanchez & Perez, 2001). Waste of Resources: Excessive inventory, unnecessary movement, and rework due to errors all contribute to resource wastage (Liker, 2004). By addressing these challenges through lean principles, auto repair shops can optimize their layouts and processes.

## 2.2 Lean Tools for Optimizing Layout and Processes

### 2.2.1 5S Methodology

The 5S framework (Sort, Set in order, Shine, Standardize, and Sustain) is commonly used to organize and standardize workspaces in auto repair shops (Osada, 1991). This methodology improves workplace organization, reduces tool search times, and ensures that workspaces are ergonomically arranged for optimal efficiency. Research shows that implementing 5S in automotive service environments reduces cycle time and improves productivity (Dale & McQuater, 1998).

### 2.2.2 Value Stream Mapping (VSM)

VSM is a tool used to visualize and analyze the flow of materials and information required to deliver a product or service. In auto repair shops, VSM helps in identifying bottlenecks, redundant processes, and waste points, allowing management to design an optimized workflow (Rother & Shook, 2003). Studies have demonstrated that using VSM can reduce lead time by up to 50% in automotive service centers (Seth & Gupta, 2005).

### 2.2.3 Kaizen (Continuous Improvement)

Kaizen focuses on continuous small improvements that accumulate into substantial performance gains over time (Imai, 1986). For auto repair shops, this involves continuously refining processes based on daily feedback from mechanics and other shop staff. Evidence shows that Kaizen, when systematically applied, leads to sustained productivity gains in auto repair facilities (Bessant & Caffyn, 1997).

### 2.2.4 Kanban (Pull System)

Kanban is a scheduling system that aligns the production process with actual demand, minimizing excess inventory and work-in-progress (WIP) (Sugimori et al., 1977). In the context of auto repair shops, Kanban can be used to manage parts inventory, ensuring that the right parts are available when needed without overstocking. A study on service operations found that Kanban significantly reduces waiting times and material handling inefficiencies (Holweg & Pil, 2001).

## 2.3 Cellular Layout Design

Cellular layout design groups machines and tools used for similar repair jobs into a work cell. This approach minimizes unnecessary movements and transitions between workstations (Chase et al., 2005). Cellular layouts in auto repair shops lead to better workflow, reduced lead times, and improved space utilization (Slack et al., 2016).

### 2.3.1 Optimizing Auto Repair Shop Layout

An optimized auto repair shop layout should prioritize flow, flexibility, and minimal movement of tools, parts, and personnel. Several studies have demonstrated the impact of layout redesign in automotive service centers. For example, **Ahmed and Sultana (2012)** found that using lean techniques such as work cells and U-shaped layouts in an auto repair facility resulted in a 35% increase in productivity.

Furthermore, a layout that incorporates ergonomic principles enhances worker satisfaction and reduces the risk of injuries, which leads to fewer work disruptions and consistent performance (Pun et al., 2015).

## 2.4 Lean Manufacturing and Performance Improvement in Auto Repair Shops

Applying lean principles in auto repair shops has been shown to improve overall performance, particularly by: Reducing Waste: Lean helps eliminate unnecessary movements, excessive inventory, and rework, leading to better time and resource utilization (Bhamu & Singh, 2014). Increasing Efficiency: By streamlining the repair processes, auto shops can service more vehicles in less time, improving customer satisfaction and shop throughput (Shah & Ward, 2007).

**2.4.1 Enhancing Quality:** Lean practices like Kaizen and 5S improve the overall quality of work, as mechanics operate in organized, well-maintained environments where errors are minimized (Womack et al., 1990).

### 2.4.2 Case Studies in Lean Implementation for Auto Repair

Several real-world examples illustrate the positive impact of lean principles on auto repair shops:

**Toyota's T-TEN Program** (Toyota Technical Education Network) incorporates lean principles into automotive training programs, emphasizing the importance of efficient layout design, waste reduction, and standardized work practices (Toyota, 2013). **GM's Auto Repair Centers** applied lean techniques such as Kanban and 5S, resulting in significant reductions in repair time and parts inventory (LaHood & Taylor, 2011).

**Table 1: Standard Times and Production Goals for Key Operations in Automobile Repair Plant**

| Operation | Machine | Standard time (Minutes) | Goal (pieces per hour) |
|---|---|---|---|
| Air Conditioning System Repair unit | | | |
| Inspection and Diagnosis | Refrigerant leak detector, gauge set, and scan tool | 15 | 4 |
| Recovery of Refrigerant | Refrigerant recovery machine | 20 | 3 |
| Evacuation of System | Vacuum pump | 30 | 2 |
| Recharge of Refrigerant | Refrigerant recharge machine | 20 | 3 |
| Performance Test | Gauge set and thermometer | 10 | 6 |
| | | | |
| Transmission System Repair unit | | | |
| Removal of Transmission | Transmission jack cherry picker, and engine hoist. | 60 | 1 |
| Disassembly of Transmission | Specialized transmission tools (snap ring pliers, bearing puller) | 90 | 0.67 |
| Inspection and Diagnosis | Inspection light, magnifying glass, and diagnostic software | 45 | 1.33 |
| Refilling of Transmission Fluid | Transmission fluid pump and filter | 15 | 4 |
| Testing of Transmission | Transmission test equipment (pressure gauge, flow meter) | 30 | 2 |
| | | | |
| Engine system repair unit | | | |
| Cylinder Honing and Boring | Cylinder Boring Machine | 60 | 1 |
| Crankshaft Grinding | Crankshaft Grinding Machine | 45 | 1.33 |
| Fuel Injector Cleaning and Testing | Ultrasonic Injector Cleaning Machine | 30 | 2 |
| Valve Grinding and Lapping | Valve Grinding machine | 45 | 1.33 |
| Engine Block Surfacing | Surface Grinding Machine | 60 | 1 |
| | | | |
| Auto Body system repair unit | | | |
| Dent Removal | Paintless Dent Repair (PDR | 30 | 2 |

| **Frame Straightening** | **Frame Straightening Machine (Frame Rack)** | **120** | **0.5** |
|---|---|---|---|
| Panel Replacement: | Spot Welder | 60 | 1 |
| Painting and Refinishing | Spray Booth | 90 | 0.67 |
| Rust Repair and Prevention | Sandblaster | 45 | 1.33 |
| | | | |
| Electrical system repair unit | | | |
| Battery Testing and Replacement | Battery Tester / Battery charger. | 15 | 4 |
| Alternator Testing and Repair | Alternator Tester: | 30 | 2 |
| Starter Motor Testing and Repair | Starter Bench Tester / current Probe | 30 | 2 |
| Electrical Wiring and Circuit Diagnosis | Diagnostic Scan Tool | 45 | 1.33 |
| Lighting System Repair | Headlight Aiming Machine / Oscilloscope | 20 | 3 |

**2.4.3 Servicing Capacity:** The average real maximum servicing capacity of our auto repair shop was 250 vehicles per month during the last half of 2022. However, a review of performance revealed that there was no record of equipment downtime or other shortcomings in the process, and no standardized time studies to determine the maximum installed capacity of the shop along with bottlenecks. This implies that no corrective planning and scheduling is being done, leading to cost overruns, delays, and various forms of waste.

**2.4.4 Time studies**: To establish a baseline productivity level, a time study was conducted to determine the standard processing time and hourly servicing for each operation. The results of this study are summarized in Table 1. Table 1 provides the standard times for various operations in the automobile repair shop, along with the corresponding production goals in terms of pieces per hour. It shows the initial productivity level, to fine the standard time and number of pieces serviced per hour a time study was introduced.

**2.4.5 Air conditioning system repair unit**

The Air Conditioning (AC) System Repair Unit in an automobile repair plant is responsible for maintaining, diagnosing, and repairing vehicle AC systems. This unit ensures that vehicles provide a comfortable cabin environment, especially in regions with extreme temperatures.

#### 2.4.6 Transmission System Repair Unit

The Transmission System Repair Unit is essential for maintaining and repairing the transmission systems of vehicles. The transmission is a critical component that transfers power from the engine to the wheels.

#### 2.4.7 Engine System Repair Unit

The Engine System Repair Unit is responsible for diagnosing and repairing engine-related issues. The engine is the heart of the vehicle, and its proper maintenance is crucial for vehicle performance.

#### 2.4.8 Auto Body System Repair Unit

The Auto Body System Repair Unit handles repairs and refinishing of the vehicle's exterior. This unit focuses on restoring the vehicle's appearance and structural integrity after collisions or wear.

#### 2.4.9 The Electrical System Repair Unit

The Electrical System Repair Unit focuses on diagnosing and repairing the vehicle's electrical components. Modern vehicles rely heavily on electronics for various functions.

### 2.5. Initial installed capacity calculation

From table 1, it can be deduced that the constraint or the bottleneck is at the Frame Straightening which will take almost 240 minutes to service a particular vehicle in terms of Frame Straightening. Due to the Location, the Shop Size and Capacity, the wide range of services, the pricing and the customer relationship, the average monthly service for the auto repair shop is 250 vehicles per month.

$$\boldsymbol{Installed\ capacity} = No.of\ vehicle\ serviced/hour * 7.5\ hour/turn * 3\ turns/day * 25\ day/month \quad (1)$$

#### 2.5.1 Overall equipment effectiveness (OEE) calculation.

$$OEE = \frac{Actual\ units}{Possible\ units} \quad (2)$$

#### 2.5.2 Identification of causes that lead to low productivity in the auto repair shop

To pinpoint the sources of inefficiencies and low productivity, the 5MQS method (a methodology for identifying waste related to machines, methods, materials, manpower, management, safety, and quality) was employed. This was further enhanced by utilizing an Ishikawa diagram to analyze the root causes. The overall findings.

**2.5.3 Equipment:** Flow diagrams and diagnostic tool usage charts were used to analyze the equipment layout and processes, revealing a poor distribution of tools and machinery within the shop. Additionally, there are frequent stoppages for equipment repairs, and there is no preventive maintenance program in place.

**2.5.4 Methods:** Time studies indicated that the most critical activity (bottleneck) is the Frame Straightening unit suggesting that productivity needs to be improved at this workstation.

**2.5.7 Workload Distribution**: Diagrams illustrating interactions between technicians and machines, as well as between different machines, highlighted a significant imbalance in workload among the various stations and operators.

**2.5.8 Time Wastage**: Significant time is wasted searching for tools and equipment, as they are not stored in designated areas and are often located far from the workstations. There is also a high level of inefficiency due to unnecessary movement of parts and personnel caused by the poor layout of equipment in the shop.

**2.5.9 Material Storage**: There is no clearly marked area for storing spare parts and raw materials, leading to frequent obstructions that disrupt both personnel movement and the flow of work through the shop.

To assess the level of compliance with the 5S methodology, checklists were created and utilized to measure adherence. The results are shown in Table 2 and depicted in Figure 1. The 43% compliance rate for the 5S in the auto repair shop highlights the need for further implementation of the 5S principles.

**2.6 Materials**: There is a significant build-up of inventory at critical points in the workflow, indicating an imbalance in the service process and a lack of organization in the storage of materials.

The 5S audit is a systematic approach used in lean manufacturing to organize and manage the workspace efficiently, ensuring that everything is in its place and maintained properly. The 5S methodology consists of five phases: **Sort**, **Set in Order**, **Shine**, **Standardize**, and **Sustain**. Each of these phases focuses on a specific aspect of workplace organization:

**Sort**: Removing unnecessary items from the workspace.
**Set in Order**: Organizing and arranging tools and equipment for easy access and efficiency.
**Shine**: Cleaning the workspace and keeping it tidy.
**Standardize**: Establishing standards and procedures to maintain the first three phases.
**Sustain**: Maintaining and reviewing the standards, ensuring continuous improvement.

This **table 2** represents the results of the 5S audit for the auto repair shop, showing that the overall compliance level is 43%. This indicates areas where improvements are needed, particularly in "Sort," and "Set in Order," to enhance overall efficiency and organization in the shop.

**Table 2: 5S audit for the auto repair shop**

| 5S | Maximum Score | Auto Body system repair unit | |
|---|---|---|---|
| | | Result | % |
| Sort | 50 | 24 | 48 |
| Set in Order | 45 | 16 | 40 |
| Shine | 45 | 11 | 70 |
| Standardize | 25 | 18 | 50 |
| Sustain | 30 | 14 | 71 |
| Total | 195 | 83 | 43 |

$$Overall\ compliance\ level = \frac{Total\ achieved\ score}{Total\ maximum\ score} * 100\% \quad (3)$$

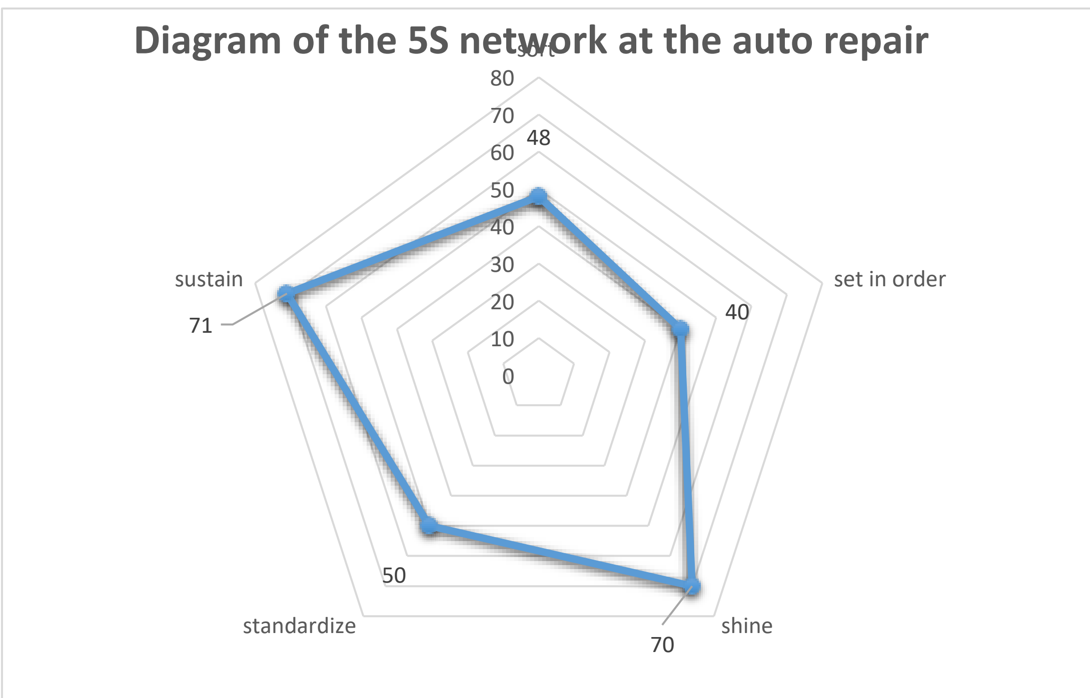


**Fig. 1. The Radar Chart diagram of the 5S network at the auto repair shop before training**

The "Sort" phase involves removing unnecessary items from the workspace and keeping only what is essential. A score of 48% suggests that the unit needs better organization by removing unused tools or materials, thus creating a more efficient work environment. Improvement here would streamline operations and reduce wasted time.

Set in Order" emphasizes arranging tools and equipment for easy access. The score of 40% is quite low, highlighting the need for better spatial organization. Improving this would save time and effort when locating necessary tools, improving workflow and productivity.

Shine" refers to maintaining cleanliness and order in the workplace. A score of 70% is relatively better compared to the other categories, suggesting that the unit maintains a fair level of cleanliness. However, there is still room for improvement to achieve optimal standards of cleanliness and safety in the workspace.

The "Standardize" phase ensures that the previous steps (Sort, Set in Order, and Shine) are consistently applied through routines and best practices. A score of 50% implies that there is some standardization in place, but further efforts are needed to consistently maintain order and cleanliness.

"Sustain" focuses on maintaining and improving the established standards over time. With a score of 71%, this area is relatively strong. However, continuous monitoring and commitment to the 5S principles will help further improve and sustain these standards long-term.

The overall compliance level is 43%, which indicates a need for substantial improvement across the board. The weakest areas are **Set in Order (40%)** and **Sort (48%)**, which both focus on organizing the workspace. These areas should be prioritized for improvement to enhance the efficiency of the auto body system repair unit.

**2.6.1 Sort**: Remove unnecessary tools, parts, and materials from the work area to reduce clutter and confusion.

**2.6.2 Set in Order**: Implement visual management tools like labels, tool shadow boards, and color-coding to organize tools for quick identification and access.

**2.6.3 Shine**: Build on the existing cleanliness practices and encourage a culture of workplace cleanliness to prevent accidents and improve morale.

**2.6.4 Standardize and Sustain**: Ensure that all workers follow consistent procedures and implement a system for regular audits to maintain improvements over time.

## 3.Materials and Methods

After evaluating various continuous improvement methodologies, lean manufacturing principles were selected to enhance the layout and processes of the automobile repair plant. The Kaizen framework was employed to guide the improvements. The project was executed in seven phases as outlined in Table 3.

**Table 3: The Kaizen framework**

| Phase | Subject | Objective | Activities |
|---|---|---|---|
| Phase 1 | Formation of Kaizen Teams | Establish teams dedicated to continuous improvement within the repair plant. | Training on lean manufacturing techniques including 5S (Sort, Set in Order, Shine, Standardize, Sustain), time loss analysis, standardized work procedures, and visual management. Training on Overall Equipment Effectiveness (OEE) to measure and improve equipment performance. |
| Phase 2 | Initial Situation Assessment | Evaluate the current state of the repair plant's layout and processes. | Conduct a comprehensive assessment of workstations using photographic evidence, data collection, and analysis. Identify inefficiencies and areas for potential improvement in workflow, space utilization, and equipment placement. |
| Phase 3 | Definition and Approval of Work plan | Develop and validate a detailed plan for implementing improvements. | Each Kaizen team presented findings from the initial assessment and proposed a work plan including timelines, goals (performance indicators), responsibilities, and necessary resources. Management reviewed and approved the proposed plans to ensure alignment with organizational objectives. |
| Phase 4 | Development and Implementation of Standards | Establish standardized procedures to ensure consistency and efficiency in operations | Document best practices identified by the Kaizen teams in the repair and maintenance processes. Implement these standards across all relevant workstations and operations within the plant. |

| | | | |
|---|---|---|---|
| Phase 5 | Standardized Training and Implementation of Improvements | Ensure the workforce is proficient in new procedures and improvements are effectively integrated | Utilize a "learning by doing" approach to train staff on new standards. Make real-time adjustments to optimize processes based on feedback and performance monitoring. |
| Phase 6 | System Management and Operationalization | Integrate the new standards and improvements into the daily operations of the plant. | Standardize the new operational processes, ensuring that they become part of the routine workflow. Implement a continuous improvement cycle, regularly reviewing and refining the processes to maintain optimal performance. |
| Phase 7 | Closure of Initial Kaizen Projects and Future Planning | Conclude the first phase of improvement projects and plan for ongoing development. | Close the initial Kaizen projects, reviewing the outcomes and documenting lessons learned. Commit to new continuous improvement projects, setting the stage for the next phase of process enhancements |

### 3.1 Implementing improvements through the strategic use of lean manufacturing tools.

#### 3.1.1 Machines

In optimizing the automobile repair plant, the focus started with balancing the workload across different workstations. A new layout was implemented to streamline operations and minimize bottlenecks. Standardized Work roundtables were introduced in each repair cell, ensuring that documentation of standardized procedures, visual aids, measurement tools, necessary equipment, identification of non-conforming parts, containers for personal protective equipment, and proper lighting are all in place to support efficiency.

A basic preventive maintenance program was also initiated to minimize unexpected machine breakdowns, thereby ensuring consistent workflow and reducing downtime.

### 3.2 Method

To tackle critical operational challenges, a human-machine diagram was used to design a balanced repair cell for critical processes. This method was extended to other critical areas within the plant, leading to smoother operations.

A standardized form was created to log daily servicing outputs, along with planned and unplanned machine stoppages. This data is used for the ongoing calculation of Overall Equipment Effectiveness (OEE), which is now a key performance indicator for each machine and repair line. Root cause analysis tools, such as Pareto and Ishikawa diagrams, are employed to identify and address underlying issues, driving continuous improvement.

Visual management techniques were implemented to display OEE and other critical performance indicators in real-time, promoting transparency and accountability among the workforce. The standardization of work practices was reinforced by documentation created by Kaizen teams, covering the following:

**3.2.1 5S Audits:** Each repair station now has a 5S checklist that operators complete at the beginning of their shifts, evaluating the organization and cleanliness of their work area. Non-compliance issues are recorded on the reverse side, with a designated individual responsible for resolving them by a specified date.

**3.3.1 5S Standard Card:** This card is present at every repair station, detailing the necessary materials, tools, information, and safety requirements for each task.

**3.4.1 SMS and SMI Sheets:** Standard Manufacturing Sheets (SMS) for cyclical operations and Standard Manufacturing Instructions (SMI) for each process were developed, leading to optimized process variables and increased capacity at bottleneck areas.

**3.4.1 Material:** Material handling improved significantly through the reorganization of the plant layout and the application of 5S principles. Standards for material control were established, and personnel received training to handle materials efficiently, reducing waste and delays.

**3.4.2 Man:** Standardized training programs were implemented based on the procedures developed by the Kaizen teams. These training materials are continuously updated and used for both ongoing retraining and orientation of new employees. A tiered training system was established, with operators advancing through five levels:

1. Basic training (20%)
2. Approved for operations (40%)
3. Approved for fine-tuning (60%)
4. Approved to train others or perform rework (80%)
5. Capable of applying lean manufacturing principles (100%)

By the end of the first half of the year, it was expected that the operational staff would have achieved at least a 40% competency level in their respective roles. A multi-functionality matrix was developed to track and display the training level and capabilities of each operator, allowing for better resource allocation and flexibility.

**3.4.3 Management:** Process improvements at critical bottlenecks included the introduction of statistical process control, enhanced training for staff, and improved lighting conditions to support precision work.

**3.4.4 Safety:** Protective gear is readily available and mandatory at each work station, ensuring compliance with safety standards. Safety protocols are strictly enforced, with regular checks to ensure that all operators are equipped with the necessary protective equipment before beginning their tasks. This commitment to safety reduces the risk of workplace injuries and promotes a secure working environment.

**3.4.5 Quality** The Kaizen teams took proactive steps to improve quality by conducting thorough root cause analyses using the Ishikawa (fishbone) diagram. This method allowed them to identify underlying issues that were affecting repair quality. Corrective actions were promptly implemented to address these root causes, leading to a significant improvement in the overall quality of work. Continuous monitoring and adjustments ensure that quality standards are maintained at all stages of the repair process.

## 4. RESULTS AND DISCUSSIONS

Figure 2 shows the network diagram showing the results of the 5s standards after the trainings. an increased level of compliance can be observed. however, more improvement is needed in the s with the lowest compliance level: Shine. The radar chart demonstrates significant improvement across all categories after the 5S training, with scores ranging from 70% to 93%. These high percentages reflect that the training was effective in enhancing workplace organization, cleanliness, standardization, and long-term compliance. The lowest score is in the "Sort" category at 70%, which shows there’s still room for improvement in removing unnecessary items and keeping only the essentials at workstations. The radar chart reflects a strong post-training performance with most areas scoring above 80%, indicating a well-organized, clean, and efficient workplace. The team has successfully implemented 5S practices, particularly in sustaining the improvements made.

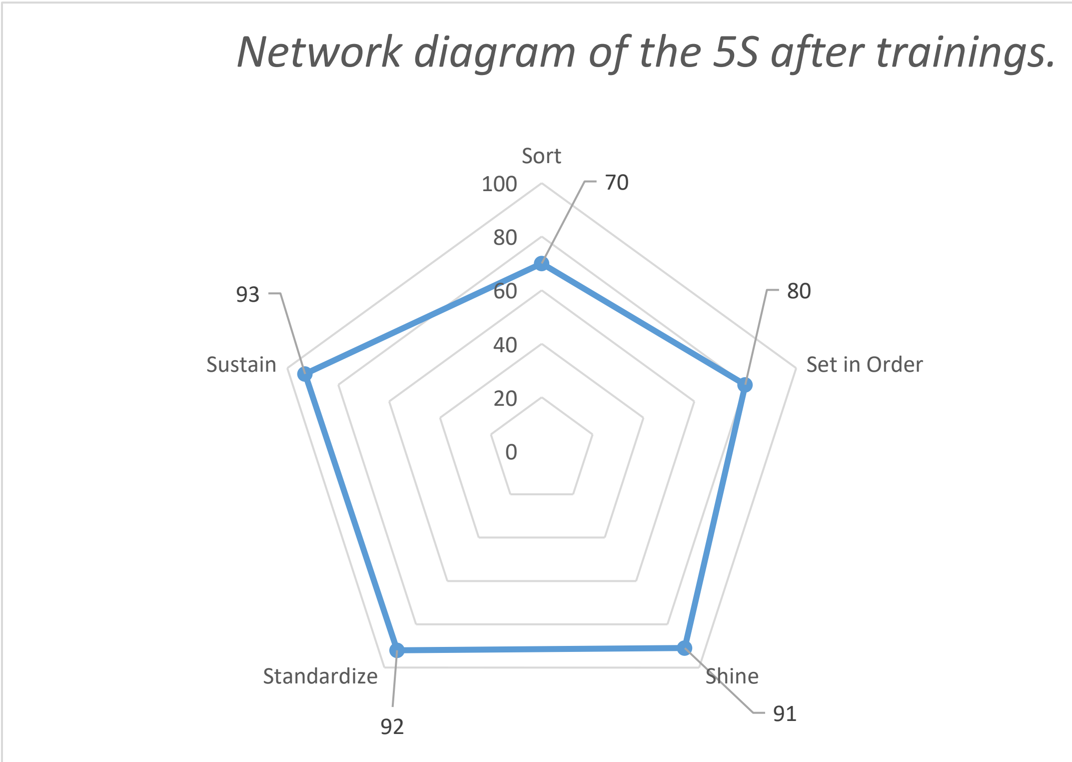


**Fig. 2: Radar Chart Diagram of The 5S Network at The Auto Repair Shop After Training**

**Table 4: 5S Performance Evaluation Before and After Training**

| 5S | Maximum Score | Before Training Result | Before Training % | After training Result | After Training % |
|---|---|---|---|---|---|
| **Sort** | 50 | 24 | 48 | 35 | 70 |
| **Set in Order** | 45 | 16 | 40 | 36 | 80 |
| **Shine** | 45 | 11 | 70 | 41 | 91 |
| **Standardize** | 25 | 18 | 50 | 23 | 92 |
| **Sustain** | 30 | 14 | 71 | 28 | 93 |
| **Total** | 195 | 83 | 43 | 163 | 84 |

**Table 4** represents the 5S performance in different areas after training, below is the break down and the interpretation based on each category and the percentages shown:

**Sort** (70%): This indicates that the workspace organization (sorting out unnecessary items) has improved significantly after training, reaching 70% compliance. This means that most of the unneeded items have been removed, but there is still room for improvement.

**Set in Order** (80%): The organization of tools and materials is at 80%, indicating a well-organized layout at the workstation. This helps ensure that everything is in its proper place, improving efficiency and workflow.

**Shine** (91%): The "Shine" score has greatly improved, now at 91%. This reflects excellent cleaning practices at the workstation, suggesting that the area is being regularly cleaned and maintained, with only minimal further improvement needed.

**Standardize** (92%): This high score suggests that standard operating procedures (SOPs) have been successfully implemented. The workers are following standardized processes, contributing to consistent quality and efficiency.

**Sustain** (93%): The "Sustain" score is the highest at 93%, which reflects a strong commitment to maintaining and upholding the 5S practices over time. This means that the team is regularly checking and ensuring that the improvements made during training are continuously adhered to.

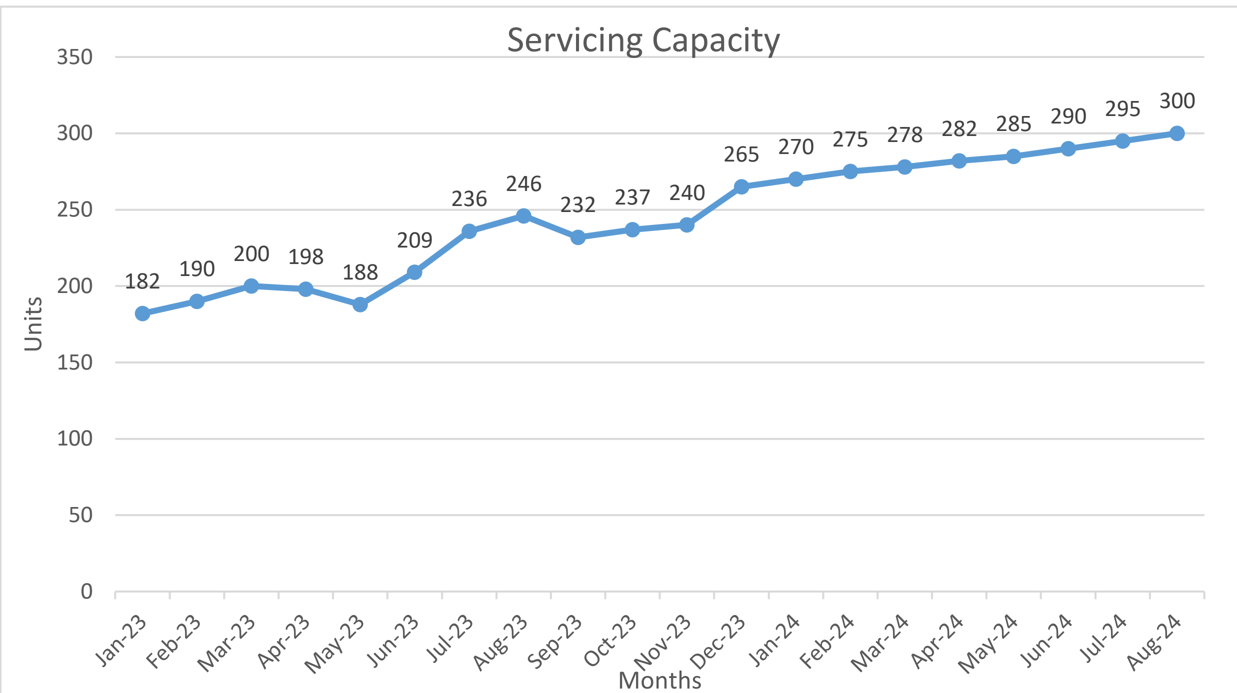


**Fig. 3: Graph of Servicing capacity against the time**

**The X-Axis (Months) is** the time span which covers 20 months, from January 2023 to August 2024. The **Y-Axis (Units) is** the servicing capacity is measured in units, ranging from 0 to 350.
There is a general upward trend, indicating a gradual increase in servicing capacity over time. Initial State (Jan 2023): The servicing capacity starts at 182 units in January 2023. Steady Growth (Jan 2023 – July 2023): From January to July 2023, the capacity shows a consistent rise, increasing from 182 units to 209 units. This indicates a relatively moderate growth period. Between July and

August 2023, there's a substantial increase from 209 to 236 units. This suggests a potential upgrade in capacity or improvement in operational efficiency during this period. After the August peak, the graph shows some minor fluctuations between August and December 2023, where the capacity drops slightly in September (from 246 to 232 units) and then recovers by December to 240 units. This indicates variability in performance, possibly due to resource constraints or external factors. From January 2024 onward, the capacity stabilizes and grows at a steady rate, starting at 265 units in January 2024 and rising incrementally to 300 units by August 2024. This implies continuous improvement and optimization in the system, with fewer fluctuations.

The most noticeable peaks occur in August 2023 (246 units) and December 2023 (240 units). The most significant decline happens in September 2023, where the capacity drops from 246 units to 232 units. A relatively flat period occurs between March 2024 and April 2024, where capacity remains consistent at 275-278 units, before continuing its steady rise.

**Capacity Improvements:** The increase in servicing capacity is due to operational improvements, better resource allocation and increased demand over time.

**Fluctuations (Mid-2023):** The dip in capacity during mid-2023 suggests either temporary inefficiencies, maintenance, or resource limitations that were later resolved.

**Stable Performance (2024):** The smooth growth during 2024 indicates that the system has reached a phase of sustained improvement, with processes optimized and stabilized. The graph shows a clear trend of improvement in servicing capacity over time, with some fluctuations that could indicate short-term challenges. The overall trajectory is positive, particularly from late 2023 to mid-2024, suggesting successful adjustments or growth strategies that were implemented during this period. If this relates to a specific project or system, further insights could be drawn based on additional context.

## Conclusion

The application of lean manufacturing principles to automobile repair plant layout and processes offers a powerful approach to improving efficiency, reducing costs, and enhancing customer satisfaction. By defining value, mapping the value stream, creating a future state, implementing pull, and pursuing perfection, repair plants can achieve significant performance improvements and remain competitive in an increasingly demanding industry. However, while this study demonstrates the effectiveness of lean manufacturing principles in optimizing auto repair shop layouts and processes, several limitations were encountered, like data constraints and implementation challenges. The data used to evaluate performance improvements was limited to a single case study, restricting the generalizability of findings across different auto repair shops with varying sizes, services, and customer bases. Practical implementation of lean tools, such as Value Stream Mapping (VSM) and 5S, faced resistance from employees due to the cultural shift required for embracing lean practices. Time and resource limitations made it difficult to conduct comprehensive training sessions for all employees, which could have improved adoption rates. The study focused primarily on operational efficiency and servicing capacity but did not extensively analyze other factors like environmental sustainability, customer feedback, or long-term financial impacts. These limitations suggest that while lean principles offer significant potential, their full effectiveness depends on context-specific factors and the extent of organizational commitment. Future studies should expand the scope to include multiple auto repair shops of different scales and geographical locations to better understand how lean principles can be tailored to diverse environments. Research can explore how emerging technologies, such as IoT sensors, AI-driven predictive maintenance, and digital twins, can complement lean practices to further enhance shop layouts and processes.

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