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The Effectiveness of the Manufacturing Process of Automotive Door Hinges: A Case Study

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Abstract

The paper seeks to determine the manufacturing productivity parameters used in the automotive industry in South Africa. The downtimes, rejects, rework, takt times and quality of the products in both the night and day shift were found to be effective. The parameters caused bottlenecks which increased the takt times through the manufacturing 4Ms, namely materials, methods, machines and manpower. Durations of each downtime for each M were recorded and the root cause established using the 5WHY interrogation. The theory of Constrains and Lean Manufacturing tools were applied to subordinate and minimize the cause of problems through continuous improvement (CI). The machine downtimes, rework, reject, methods failures and any inconsistencies-initiated CI in the automotive industry. A layered process audit was done by line managers to get the defect trend using root cause analysis before standardization. The safety of staff and machines was audited to establish and eradicate the near miss and sustain the lock Out, Tag out (LOTO).

Keywords
Downtimes, constraints, 4Ms, lean, changeover times, quantitative and qualitative.

1. Introduction
1.1 Background
The manufacturing process for the Automotive industry metal parts starts with the raw material bars or sheets that are added value by machining to produce the required shapes by removing excess materials or forming. The application of Lean tools reduces costs by optimizing defects to improve the quality of the products and enhance sustainability of the manufacturing. The size and shape of the product is specified by the product design whilst the manufacturing uses six sigma limits to meet customer requirements (Rojas, Rubí Rivera Barzallo and Cornejo 2025).

The automotive industry uses the six-sigma principle to control the production and quality of auto parts. The parts must fall within the acceptable range. Undersize parts outside the acceptable range are deemed rejects and the materials can be recycled. Oversize parts call for rework and additional manufacturing costs from the labor, machines, energy to mention but a few.

The metal manufacturing industry uses turning, milling machines, plasma cutters, and bench drills that require clearly defined arrangement, stores and pathways for handling materials to reduce the operational times and costs that increases the unit costs. The application of the 7S tool is critical in manufacturing to reduce the eight wastes and operational costs (Oleksiak, Żyszczyński and Micor 2025).

The change overtimes for production tools are optimized by the lean Single Minute exchange of dies (SMED) that was adopted by the automotive industry in South Africa (SA). The automotive industry in SA manufacture parts for more than five organizations that have assemble plants in the region. If change over times are not optimized, manufacturing costs will increase to lower profitability in the global market.

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(Zainab Eldardiry 2021) and (Niekurzak, Lewicki, Coban and Bera 2023) singled out SMED as a tool used to determine the degree of machine utilization a key factor for assessing energy efficiency. The tool can adjust to the changing customer needs and reduce the burden of operators in changing the layout of the lines and modifying the changeover tool trolleys and tool locking system at the stations. Figure 1 shows a model that was developed for the SMED. The process starts with an investigation to identify the process deficiencies which will be quantified analysed and improved to control the changeover times to minimum.

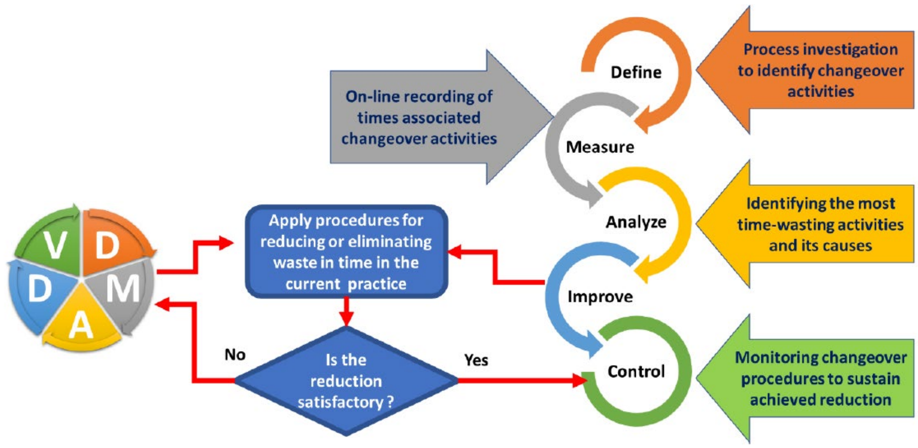

Figure 1. The proposed conceptual framework for changeover time reduction (Zainab Eldardiry 2021)

The study will consider the model and use it where appropriate to control the change overtimes. Standard operating conditions will be developed for each auto part for different customers. The personnel will be trained to the interchangeable dies, fixtures and jigs developed by the R&D department using the Poka Toka lean principle.

1.2 Aims and objectives

The study aims at establishing the effectiveness of improving the quality of a product without increasing the cost as is done by conventional non-lean manufacturers that increase the costs for the quality to improve.

1.3 Scope

The study seeks to establish the effectiveness of manufacturing processes in the automotive industry for a car door hinge manufacturing company.

1.4 Significancy

The study will enhance the sustainability of the manufacturing processes in the automotive Supply chain and other industries by restricting the eight wastes.

2 Literature review

2.1 Literature overview

The automotive manufacturing industry determines the efficiency and effectiveness of the processes by both quantitative and qualitative analysis. The method of manufacturing and philosophy of the organization is instrumental in improving quality and effectiveness of the organization. Today many manufacturing organizations have adopted Lean manufacturing methodologies to reduce waste whilst improving quality and effectiveness. The Lean six sigma (LSS) method is used extensively in the automotive industry (Gomaa 2022) (Figure 2).

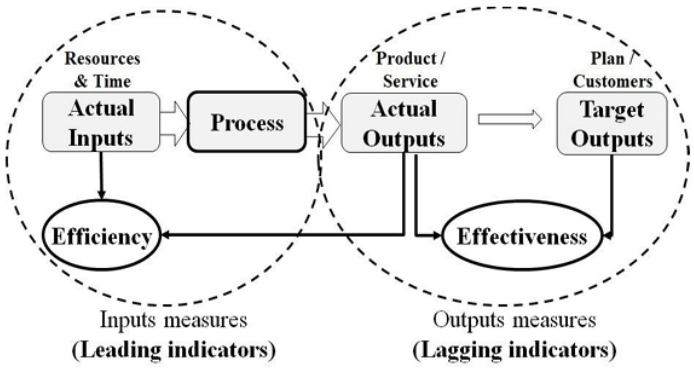

Figure 2. The efficiency and effectiveness of manufacturing (Gomaa 2022)

2.1 Quantitative

Downtime in production lines poses significant challenges to manufacturing efficiency, leading to financial losses and reduced productivity. Manufacturing strives to reduce waste and increase Overall Equipment Effectiveness (OEE) by managing and keeping the machine tools running without untimely stoppages to increase the uptime. Costs associated with production losses must be eliminated by the maintenance strategy employed. Total productive maintenance (TPM) strategy improves the plant uptime by reducing breakdowns. To optimize efficiency and effectiveness, the plant availability for each shift is increased by improving the (OEE). The mode of operation, quantity of machines, number of breakdowns interventions and production out comes are used to evaluate the plant effectiveness (Rojas, Rubí Rivera Barzallo and Cornejo 2025).

In the study the OEE needs to be increased to the global standard of above 70% by improving the 4Ms using an autonomous TPM strategy. TPM empowers the operators to stop and adjust the production machine tools when there is a looming error. Major maintenances are done by specialized maintenance teams after reading the machine history. (Valerie Contreras-Rios1 2025) indicated that metal industry with poor operational efficiency, lead to non-compliance in delivery times. This impacts lead times, order delays and decreased product quality in production processes. Line balancing is used identify and eliminate bottlenecks whilst Poka Yoke redesigns the process tools like jigs and dies to allow quick die exchanges. Time and work study analysis was used to develop a cause-effect diagram and identify the root causes of plant failure.

Figure 3 shows the cause-and-effect diagram developed by Valerie et al. The root cause analysis will be used to find the problem and develop the solution for each M.

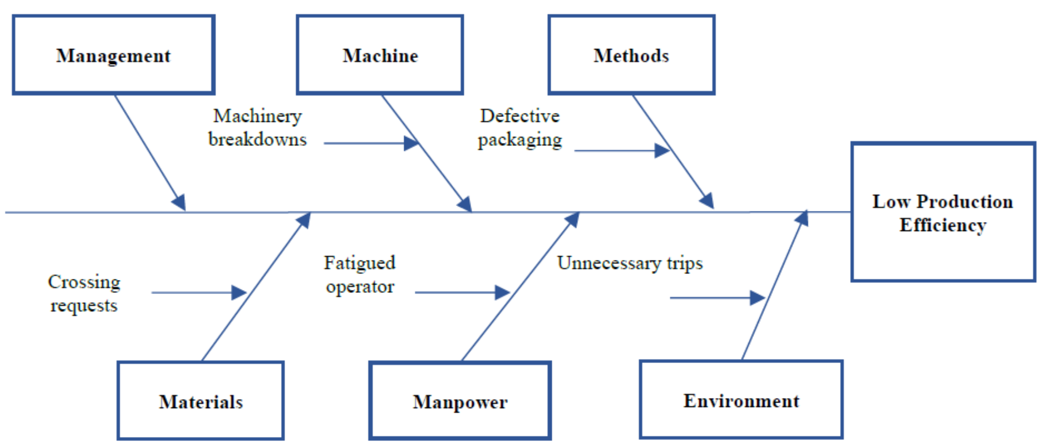

Figure 3. The Cause effect diagram for low production efficiency (Valerie Contreras-Rios1 2025)

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The statistical data in the cause and effect was used to plot the pareto curve that shows the effect of each challenge in production. Figure 4 shows the Pareto analysis of the production process with respect to LB, TPM, PY and SLP .

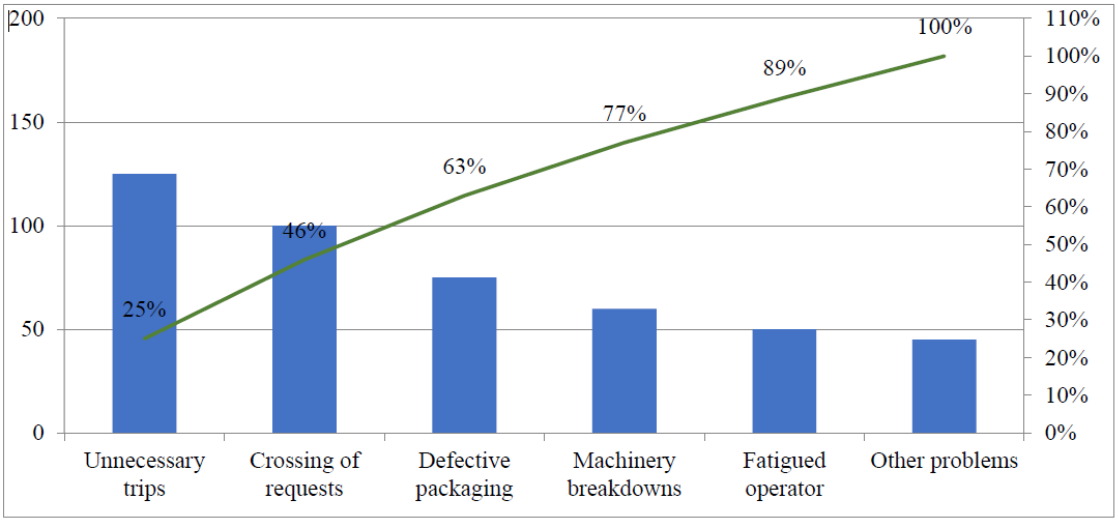

Figure 4. The pareto analysis of wastes in plant (Valerie Contreras-Rios1 2025)

The study by (Valerie Contreras-Rios1 2025) showed that combining lean manufacturing tools with automation, and optimization technics is achieving superior productivity by reducing operational costs, whilst improving quality. The overall throughput improves when resources are used with minimum waste. The automotive industry focuses on improving efficiency by optimizing processes, and systems to enhance productivity and reduce waste by analysing workflows, bottlenecks, and implementing strategies like lean manufacturing, Six Sigma, and automation.

(Rotan Kumar Saha and Md. Tutul Islam 2023) identified setup and change over processes as time consuming and no value adding process in manufacturing. Changeover time reduction are used to cut down on total process lead time with the assistance of lean manufacturing tools. Change over times can be reduced by reducing the 7 wastes and improving the SMED. After implementing improvement measures, changeover time was reduced by 18%–33%.

(Peter Malega1 2025) and (Somatkar *et al.* 2025) established that underutilization of tools and inefficient planning reduced the effectiveness of a manufacturing plant. The evaluating of production systems using OEE and workflow analysis led to the introduction of modern tools to optimize workflows by installing sensor-based predictive maintenance tools. These tools predict the occurrence of a defect before it happens and signals for adjustments and repairs to prevent defects and significant downtime. OEE enhance production efficiency and profitability by improving plant availability, performance, and quality(Igbokwe Nkemakonam Chidiebube 2025).

2.2 Qualitative

To improve productivity, education and training in the Lean tools is critical to all workers to meet the demands of a rapidly evolving industrial landscape. This addresses challenges such as workforce adaptation to technological changes and balancing automation with human intervention to transform and reshape traditional manufacturing. The analysis of non-conformities, complaints, and delivery delays, revealed improvement prospects (Ahmad 2025).

The potential of Lean Manufacturing tools such as SMED, 7S, Poka Yoke and Total Productive Maintenance (TPM) to optimise operations was realised by many industries in the Automotive supply Chain (ASC) optimize operations. The adoption and training bridges the theory and practice gaps. The study by (Callan-Villanueva, Núñez-Gonzales and Calderón-Gonzales 2025) revealed an average of 35.99% reduction in setup times, a 32.66% increase in MTBF, a 39.71% reduction in MTTR, and a 23.19% decrease in defective products when the workforce adopts lean.

The integration of Value Stream Mapping (VSM), and 5S, significantly contribute to improvements in production cycle efficiency, lead time reduction, and waste elimination to enhance sustainability, flexibility, and human-machine collaboration. (Wahyuanto and STMM MMTC Yogjakarta 2025).

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VSM examines the application of Quality Control (QC) tools in identifying and addressing the root causes of machine downtime and its impact on efficiency and productivity. QC tools such as the Pareto principle and cause-and-effect diagrams analyse and identify the underlying causes of downtime before developing a plan of action to improve overall productivity and sustainable improvement (Achal Kandoi1 2023) and(Nadia Islam Tanha* 2025).

(Gomaa 2022) and (Nadia Islam Tanha* 2025) recommends the use of Lean Six Sigma (LSS) for continuous improvement in efficiency and effectiveness. The LSS tool improves quality, and productivity whilst reducing process variation, cycle time, non-value-added time, lead times, cost and eliminating waste whilst increasing customer satisfaction. Today the ASC is using six sigma in their manufacturing plants.

3. Methodology

Time and Work-study methods are used to obtain production data to plot graphs. Work study includes the past machine history and what was used to reduce downtime. Observation identifies how TPM is practiced in the plant by observing machine operators on duty. Layered process audits are used to get the defect trend in the root cause analysis (RCA) before standardization. Occupational safety audit helps identify the near miss and sustain the lock Out, Tag out (LOTO).

The effectiveness of a manufacturing process is determined by the quality of products and how the process meets the takt times. If products are acceptable and produced at duration time the process is 100% effective. If the process has bottlenecks that increases the process time to make it higher than takt time the effectiveness falls short. The rejections, changeover times, breakdowns affect the effectiveness of the process.

4. Results

Shift A

The eight wastes in manufacturing led to the downtimes for the quarter April, May, June and July. The time losses are shown as percentages caused by the 4Ms and changeovers in Figure 5. Change overs consume production times if not properly planned and designed. Lean applies the SMED tool to reduce the changeover times and improve effectiveness. SMED is made more effective by the application of the Poka Yoke to redesign and modify the dies to use simple clamps when changing the product. The down times due to changeovers for the quarter ranged from 2 to 3 % of production time. The rejections in the same quarter ranged from 1 to 3 % of the production time. The 4Ms had highest production times where materials ranged from 8 to 11 %, methods from 10 to 12%, machines 5 to 9% and Manpower 1 to 8%.

The effectiveness of production for the whole year ranged from 54% to 69%, which is below the expected 75%. The first step in continuous improvement in the 4Ms is to identify critical areas according to lean manufacturing principles. In this case the target is to reduce all downtimes to below 5% in the materials and methods where downtimes are 10 % and above.

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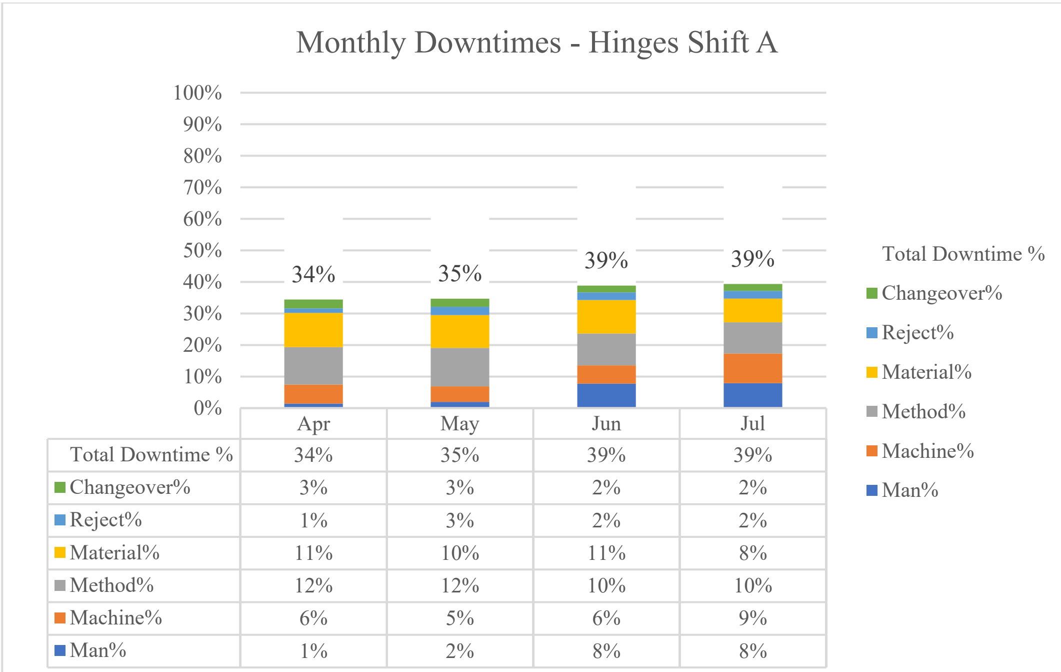

	Apr	May	Jun	Jul
Total Downtime %	34%	35%	39%	39%
Changeover%	3%	3%	2%	2%
Reject%	1%	3%	2%	2%
Material%	11%	10%	11%	8%
Method%	12%	12%	10%	10%
Machine%	6%	5%	6%	9%
Man%	1%	2%	8%	8%

Figure 5. Effectiveness of Shift A for the 2nd quarter at the Automotive industry in SA

Shift B
Table 1 shows the results of the manufacturing process effectiveness as determined by the company production team. The term effectiveness is used to describe the product impact per shift as per set targets and goals by the company. The company requires 100% effectiveness implying that continuous improvement will not stop till the target is reached.

Table 1. The effectiveness of the process

Apr	76%	Oct	63%
May	69%	Nov	61%
Jun	69%	Dec	57%
Jul	68%	Jan	56%
Aug	63%	Feb	60%
Sep	64%	Mar	58%

Figure 6 shows the quarterly effectiveness of the production of a car door hinge by the automotive industry. Monthly effectiveness was high at the beginning of the quarter but fell to 69% then 68% implying the was needed to improve the manufacturing effectiveness. Each M was analyzed to find the root cause and develop the solution.

The machines were improved and recalibrated to reduce the machine error caused by tear and wear that resulted in enlarged clearances. Bushings with reduced inside diameters were used at housings whilst some shafts were rebuilt and machined whilst waiting for new machines. Management purchased new ones that would be installed at a new site which to which the company would migrate. The R&D designed new manufacturing tools to suit the oncoming machines whilst some of the old machines were red tagged for auction. A few of the old machines were upgraded to remain as buffers in case of a bottleneck. The steel sheets used were manufactured by rolling and a color code at the edges would show the direction of rolling to guide the hinge manufacturer.

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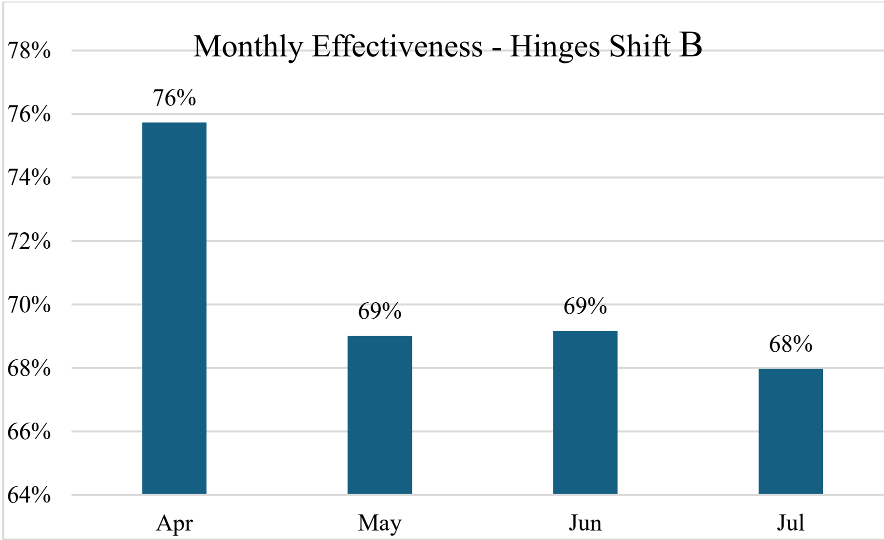

Figure 6 The effectiveness of shift B on 2nd quarter

a. Average effectiveness

The average effectiveness of shift was determined using the target and actual production The highest average effectiveness was in the months of April, August, and March whilst low averages were in December and January. (Table 2.

Table 2. Average effectiveness on hinges

Apr	68,2749417	Oct	64,7764034
May	67,6553540	Nov	56,3580811
Jun	60,2556642	Dec	54,3091560
Jul	61,9936204	Jan	58,8985262
Aug	68,05888602	Feb	64,3849850
Sep	60,0584307	Mar	68,9403771

b. Plant availability and Utilization

Plant availability measures the percentage of time equipment is operational and a high uptime is possible through effective maintenance to reduce unplanned repairs. Plant availability is determined at large by the condition of the bearings that allow smooth motion when the bearings are in good working condition. After using them wear and tear, depletion of the lubricating oils or greases may cause misalignments resulting in noise and vibrations. Utilization measures how effectively the equipment run close to maximum capacity of 80-85% rather than 100%.

Table 3 shows the planned bearing maintenance scheme for the plant to keep the plant running. If the maintenance and service is not followed a break down will happen and production will stop. The stoppage in production will affect the company and all its customers in the global market. The autonomous TPM maintenance strategy is used where the operators check and record the condition of the bearings and other plant equipment to prevent break downs. High vibrations indicate the machine is producing defective parts because of the big clearance. Bearing operating temperatures above $80C^0$implies overheating of the bearing that can cause sudden failure if not attended to in time.
The study revealed that spherical rollers for the main conveyor fell off the bearing due to damage that caused the cage to crack. The liner was worn out since it was not tightened and torqued as per ISO standards. A new liner was installed torque per ISO standards.The downtime to fix the machine reduced the production efficiency whilst running of the machine before maintenance reduced the utilization and effectiveness.

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Table 3. Bearing maintenance on machine tools and conveyor systems

Parameter	Before replacement	After replacement	Target
Vibration(mm/s)	High(>10mm/s)	<4mm/s	<4mm/s
Bearing temp(℃)	>80℃	55-65℃	<70℃
Lubrication condition	Contaminated	Clean	Within spec
Liner condition	Worn	New	Within spec

4.1 Discussions
Material productivity considers the type, structure and nature of the materials in terms of, ductility, hardness, malleability and toughness of the material when performing bending. Incompatibility with the desired mechanical properties will lead to waste that affects the effectiveness and sustainability of a manufacturing process in the automotive industry. Material waste can be improved by imparting the correct mechanical properties required at the supplier and handling operations. Further improvement comes in converting industrial waste to raw materials by recycling and waste make new materials for the market.

Methods of adding value are determined by the material properties and manufacturing tools such as jigs and dies. The R&D apply the Poka Yoke principle and CI to make jigs and dies which are simple and fast acting in compliance with SMED principle. In this case the hinges are similar but not identical for each customer, door size, closing and locking system. The change from one car model requires good and fast acting tools. The method of adding value must reduce the amount of waste generated and decrease virgin material consumption whilst improving quality and performance of the product.
The automotive industry has shifted from corrective maintenance to preventive and predictive approaches under the TPM umbrella where they can anticipate failures, schedule timely repairs, and optimize machine performance. The caused a reduction in downtime, lower maintenance costs, and increased overall equipment effectiveness. Plant availability and utilization is low when malfunctions, repairs, adjustments waiting for spares is prevalent. The Automotive Supply Chain (ASC) invested in advanced monitoring tools, employee training, and continuous performance assessments to sustain improvements.

The significance of Six Sigma in fostering a culture of continuous improvement is used for driving competitive advantage and ensuring sustainable growth in industrial engineering. Many organizations now consider improving the effectiveness by implementing Six Sigma and other Lean Manufacturing tools.

5. Future study
It is critical for other manufacturing industries to consider adopting complete lean manufacturing instead of using it as a piece meal. Many manufacturing, mining and service industries in SA have adopted the 7S, and Kanban tools only without including the whole package. Meat Abattoirs, municipalities, mines and power utilities, for instance use the TPM and Kanban systems and leave the rest.

6. Conclusions
The effectiveness of the process was determined by the quality of hinges produced in each shift. To improve the quality, the bottlenecks were first identified before the 5WHY interrogation to establish the root cause of defects. The RCA done by engineers is used to develop the solution and isolate the defect trend by standardization. Materials, damage, spills, energy waste and emissions were audited to reduce waste. Rework is used widely in automotive industry to correct some of the errors instead of scraping the metal. This however happens at an additional cost that must be budgeted for. The volume of rework is reduced by continuous improvement at each production center.
The Socio-economic, Occupational Safety and Heath, and environmental (ISO 1400) compliancy enables the automotive industry to flourish in SA. It creates job opportunities in a safe and environmentally friendly environment. The safety of the workers and machines also improves effectiveness. During maintenance the lock out, tag out (LOTO) is mandatory in the automotive industry. All machines and work benches must have appropriate ergonomical layout to allow workers proper positions at each center for sustainability. The automotive industry has standard professional practice and communication linked with the housekeeping 7S principle and teamwork. sustenance champion always

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checks and audits if standards are maintained to reduce the eight wastes. Line managers are instrumental in identifying talent and utilizing it.

Regular risk and safety assessment are done whilst the daily toolbox meetings are used to identify potential risks in the production plant. This promotes a strong safety culture that reduces incidents at the workplace. Periodic refresher training is provided at TOYOTA South Africa and inhouse training for both operators and specialized maintenance teams in line with the Lean philosophy.

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