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Logistic process improvement in automotive industry using quality tools

Cristina-Mihaela FLEACĂ
National University of Science and Technology POLITEHNICA Bucharest
Bucharest, Romania
fleaca.cristina@yahoo.ro

Radu-Marian BUJDOIU
National University of Science and Technology POLITEHNICA Bucharest
Bucharest, Romania
radubujdoiu101099@gmail.com

Prof. Dr. Ing. Irina SEVERIN
0000-002-0296-4730
National University of Science and Technology POLITEHNICA Bucharest
Bucharest, Romania
irina.severin@upb.ro

Abstract

The automotive industry continues to face numerous challenges that demand ongoing process improvement and system optimization. Incidents reported in the media have highlighted the relevant impact regarding companies' sustainability and brand image and consequently, the urgent need for stronger traceability mechanisms and faster response capabilities throughout the supply chain. This paper focuses on enhancing a key logistic process within automotive companies – the incoming material inspection – by applying the DMAIC (Define, Measure, Analyse, Improve, Control) methodology. This process is critical, as it directly influences production flow, product quality, and overall supply chain efficiency.

The DMAIC approach was selected due to its proven effectiveness in driving systematic process improvements, reducing defects, and establishing measurable control standards across manufacturing and logistics operations. Each phase of the methodology provides a structured framework with clearly defined objectives, control mechanisms, and deadlines to ensure consistent progress and accountability. Implementation of the DMAIC methodology resulted in a more transparent, standardized, and efficient inspection process. Quantitative and qualitative outcomes demonstrated significant improvements in process control and traceability. Furthermore, the initial project objectives were fully achieved and, in several instances, surpassed – validating the robustness of the applied methodology.

This analysis highlights the critical role of structured quality improvement frameworks, such as DMAIC, in managing increasingly complex logistics operations. In an industry shaped by digital transformation and sustainability imperatives, adopting data-driven methodologies fosters agility, consistency, and a culture of continuous improvement is essential. Beyond enhancing operational efficiency, such approaches strengthen collaboration, accountability, and long-term competitiveness within the automotive sector.

Keywords
process improvement, automotive industry, DMAIC methodology, incoming material inspection

1. Introduction

As the logistics department is a vital component of the production supply chain and for international trade relations (Gade et al., 2020), its continuous development and optimization must be regarded as a top priority by the company's management. Notable historical cases, such as Toyota's 2009 vehicle recalls affecting over 9 million units and Airbus's delays in A380 market entry due to weaknesses in its Product Lifecycle Management system (Norazlin et al., 2017), illustrate the significant operational and financial consequences of inefficiencies in quality control and supply chain processes. These examples underscore the urgency of implementing robust systems to reduce defects and improve responsiveness. Also, Lean practices (for instance these could be 5S (Sort, Set in order, Shine, Standardize, Sustain); Kaizen (Continuous Improvement); Value

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Stream Mapping (VSM); Just-In-Time (JIT) production; Kanban; Poka-Yoke (Error Proofing); Heijunka (Production Leveling); Total Productive Maintenance (TPM); Root Cause Analysis) were introduced into Toyota's system for creating value using minimum of resources (Albăstroiu Năstase et al., 2024).

In the automotive sector, where production is highly sensitive to delays, even minor interruptions can cause substantial losses. The trend from the last years needs the requirements for rethinking the process performance system (Dörnhöfer et al. 2016). MTTR, i.e. mean time to respond, can be a valuable key performance indicator (KPI) for incoming material inspection process in automotive industry for assessing and optimizing the Incoming Material Inspection process. Typical target ranges are between 2 and 8 hours for critical issues and 8–24 hours for major defects (Aiswarya S., 2024). Improving MTTR can be achieved through measures such as automated incident detection, employee training, standardized procedures, and predictive digital tools. This is demonstrated by Renault Group, which reduced response times and saved nearly €700 million through digital innovations (Renault Group, 2024).

Improving internal logistics in the automotive industry is crucial for reducing waste and increasing efficiency. The case study by Kocjan and Podloch (2025) highlights that unoptimized material flows and the absence of visual markings lead to unnecessary movements and time losses. The authors recommend implementing Lean tools such as 5S, visual management, and standardized procedures to create an organized and predictable environment that supports operational performance.

To systematically address process deficiencies, this study employs DMAIC methodology (Define, Measure, Analyze, Improve, Control), a structured quality improvement framework widely recognized for reducing defects and optimizing industrial processes (Subagyo et al., 2020). The application of DMAIC provides a clear structure for the entire project, enabling the selection of appropriate improvement solutions supported by the most effective Lean tools – advantages not typically offered by other frameworks (Rifqi et al., 2021). Also, the case study by Ramos et al. (2025) was conducted at a multinational automotive company, where they applied Lean tools – 5S, visual management, pull systems, and standardized work – to streamline assembly line material delivery. As a result, the company achieved significant improvements: over €108,000 in annual cost savings, reduced supply cycle time, optimized stock and ramp usage, and improved ergonomics by minimizing material handling and personnel requirements.

The DMAIC approach enables data-driven analysis of incoming material inspections, identification of root causes using tools such as Ishikawa diagrams and the 5Why method, implementation of targeted improvements, and continuous monitoring of key indicators including average response time, 24-hour deadline compliance, and frequency of recurring non-conformities.

This paper focuses on proposing an improved process for logistics departments in the automotive industry, with a particular emphasis on optimizing the Incoming Material Inspection process. By applying DMAIC to the Incoming Material Inspection process, this research aims to improve documented processes for operational efficiency, enhance supplier management, and ensure timely corrective actions, ultimately supporting continuous and efficient automotive production. The DMAIC framework can significantly reduce defects, minimize process variation, and optimize supply chain performance through mapping workflows, identifying root causes and statistical tools (Kurte et al., 2025).The study draws upon previous research as well as real-world industry challenges to highlight the critical need for enhanced traceability and faster response times. A key operational metric in this context is Mean Time to Respond (MTTR), which measures the time from the detection of a noncompliance to the initiation of corrective action.

2. Data and methods

This study focuses on evaluating the advantages of applying the DMAIC methodology to the selected process, emphasizing both the direct process improvements and the broader organizational benefits. While other continuous improvement methodologies, such as the PDCA (Plan-Do-Check-Act) cycle, are also highly valuable for enhancing the internal logistics environment (Amaral et al., 2022), the DMAIC approach was chosen for this study due to its comprehensive and data-driven framework. By systematically progressing through the five stages – Define, Measure, Analyze, Improve, and Control –, the project established a structured methodology for optimizing the Incoming Material Inspection process.

The first step of DMAIC methodology is defining the problem. Thus, the problem identified in this paper is the very large number of complaints received from the Incoming Material Inspection process during fiscal year 2023. Accordingly, the problem statement is formulated as follows: to achieve, within the Incoming Material Inspection process of an organization (for example Renault Group) a reduction in the average response time to the identification of non-compliant materials from 48 hours to 24 hours during fiscal year 2024.

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The second step of the methodology is to measure the data collected about the problem. In this stage, key activities include selecting key performance indicators (KPIs) aligned with the project objectives, collecting relevant data, applying appropriate measurement methods, using statistical analysis and data synthesis tools, and establishing a baseline that reflects the current process performance (Sushmith, 2024). KPIs are essential for monitoring and evaluating progress toward achieving the project objectives. For this project, aimed at improving the process of receiving materials from suppliers, three primary indicators were selected to provide a clear and objective measurement of performance:

1. Average response time to identify non-compliant materials – it measures the efficiency of the non-compliant materials management process.

2. Compliance with target response time – it reflects the organization's ability to meet rapid-response objectives.

3. Frequency of recurring non-conformities – it indicates the effectiveness of corrective actions and improvements in collaboration with suppliers.

For each KPI, specific calculation formulas and end-of-year targets for 2024 were defined to ensure measurable and verifiable success (1), (2), (3). These indicators collectively provide a comprehensive view of process efficiency, responsiveness, and quality improvement, enabling data-driven decision-making throughout the project.

$$\text{Average response time to identify non-conforming materials [h]} = \frac{\text{Sum of response times of all non-conformities}}{\text{Total number of cases}} \quad (1)$$

$$\text{Percentage of cases resolved within 24h [\%]} = \frac{\text{Number of cases resolved} < 24\text{h}}{\text{Total number of cases}} \times 100 \quad (2)$$

$$\text{Percentage of recurring non-conformities [\%]} = \frac{\text{Final number of recurring non-conformities}}{\text{Initial number of recurring non-conformities}} \times 100 \quad (3)$$

For each of the indicators mentioned above, a specific target was established for the end of 2024 to measure the success of the improvement project. The targets are as follows:

- Average response time to identify non-compliant materials – target of 24 hours.
- Compliance with target response time – at least 90% of cases resolved within 24 hours.
- Frequency of recurring non-conformities – 30% reduction in the number of recurring non-conforming materials.

These targets provide measurable benchmarks to evaluate the effectiveness of the implemented improvements and ensure that the project delivers tangible performance gains. Research was conducted using publicly available sources from several automotive companies. Among these, the local company Renault Group served as a key reference. Information was collected from the official website of Renault (n. d.), as well as from other reliable industry platforms.

Further, the collection of data relevant to the problem was carried out by systematically measuring the current response times to the identification of non-compliant materials (indicator 1), recording the number of cases resolved in less than 24 hours (indicator 2) and the number of recurring non-compliances (indicator 3) during fiscal year 2024.

A qualitative analysis of the data was conducted to categorize the types of complaints received in the Production Process, allowing for a synthesis of the information collected over the previous year. In addition, a quantitative analysis was performed to determine the frequency of each complaint type during 2024, as presented in Table 1.

For a statistical analysis, the data from Table 1 were organized into a Pareto diagram, shown in Figure 1, enabling the application of the Pareto principle. This analysis revealed that a small number of complaint types (approximately 20%) accounted for the majority of occurrences (around 80%). By using the Pareto diagram, it was possible to identify the complaint types that exceeded the 80% threshold and thus represent the critical issues requiring priority attention.

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Table 1. Qualitative and quantitative sorting of complaints registered in 2023

	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Non-retrievable items	13	19	32	13	20	16	11	12	10	25	20	30	**221**
Retrievable items	9	13	7	18	10	11	9	8	15	11	12	9	**132**
Labeling issues	3	0	3	5	8	9	0	1	3	6	5	7	**50**
Color/appearance not in compliance	5	6	8	5	9	12	11	8	7	9	10	15	**105**
Out of stock/shortage	8	7	9	5	3	7	6	4	5	8	6	6	**74**
Material quality issues	9	10	15	14	8	9	12	11	10	8	9	20	**135**
Contamination or dirt	9	6	8	7	10	9	2	5	9	8	6	4	**83**
TOTAL	**56**	**61**	**82**	**67**	**68**	**73**	**51**	**49**	**59**	**75**	**68**	**91**	**56**

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Applying the Pareto principle (where 20% of causes generate 80% of defects) allowed the identification of the most significant problem: the high number of non-conforming parts received from suppliers (Fig. 1). By focusing on this issue, the greatest overall improvement in the process could be achieved. Not all types of complaints were addressed due to budgetary and resource constraints, making it necessary to prioritize interventions. Consequently, the most effective solution was selected – reducing the volume of non-conforming parts –, which directly impacts the efficiency and reliability of the production process.

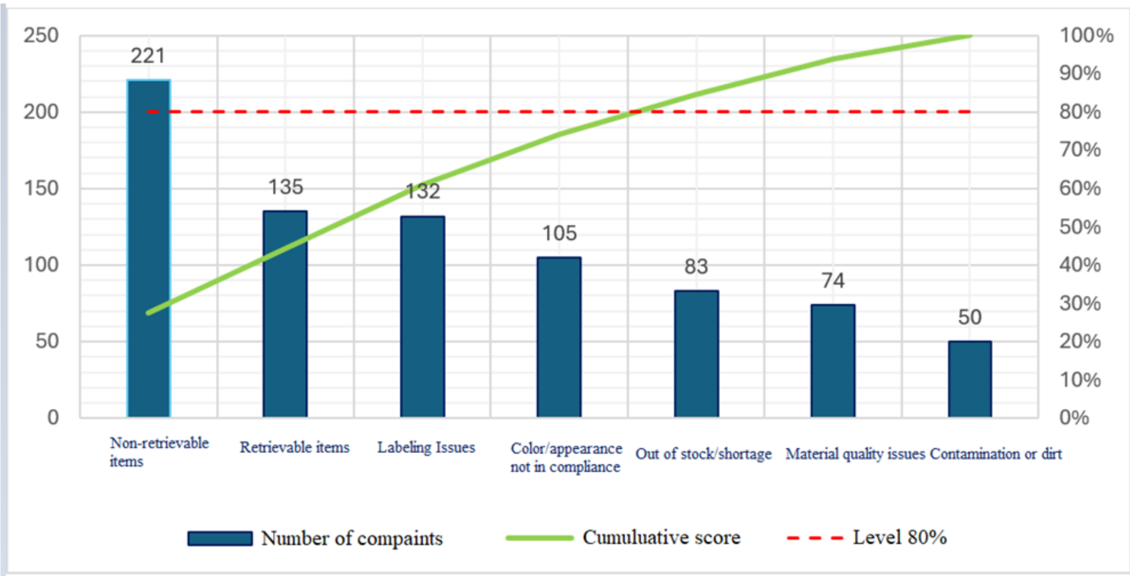

Figure 1. Pareto diagram: complaints registered in the production process during 2024

The final stage involved establishing a reference baseline to reflect the current performance level. This was represented through three graphs, each illustrating the current state of the selected performance indicators alongside the proposed targets for the following year, as shown in Figures 2, 3 and 4. These visualizations provide a clear comparison between the existing performance and the desired outcomes, serving as a benchmark for monitoring progress and guiding improvement efforts.

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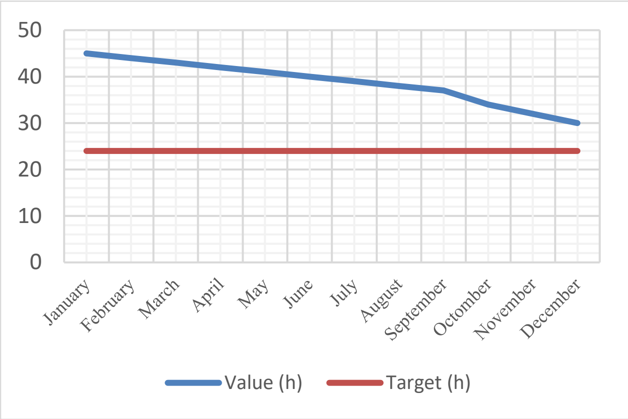

Figure 2. The current response times to the identification of non-compliant materials in years 2020–2023

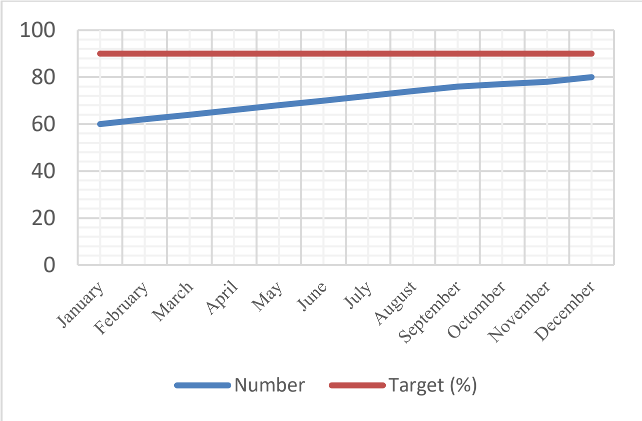

Figure 3. The number of cases resolved in less than 24 hours in years 2020–2023

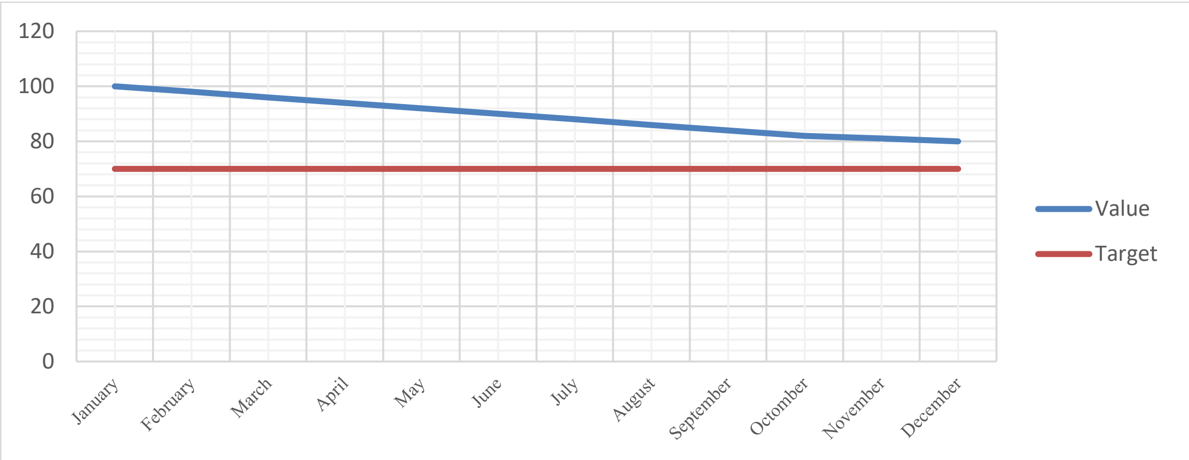

Figure 4. The number of recurring non-compliances in year 2024

The third stage of DMAIC is analyzing the data collected. In the third stage, the focus is, therefore, on identifying the root causes of the problem under investigation. In this stage, a lot of authors used a range of quality tools such as cause-and-effect diagrams, Pareto analysis, statistical process control charts, and failure mode and effects analysis (FMEA) to ensure rigorous problem identification and solution development (Che, 2016). Key activities in this stage include examining potential causes using tools such as the Ishikawa diagram and subsequently determining the root causes with methods like the 5Why approach (Sushmith, 2024). Root cause analysis and structured problem-solving tools are essential for continuous improvement in automotive logistics and the use of quality tools such as Ishikawa diagrams, DMAIC methodology, and the 5Why technique is very useful to identify and eliminate sources of inefficiency. By applying these methods, the study achieved significant waste reduction and improved delivery times, demonstrating how systematic analysis and corrective actions can enhance internal logistics performance (Amaral et al., 2022).

Building on the Pareto analysis from the previous stage, the most critical complaint was identified as "Large number of defects/non-retrievable items", which, if addressed, would produce the greatest overall improvement. To investigate the underlying causes of this issue, one of the best known models, the Ishikawa diagram (Figure 5), was employed (Luca, 2016). This tool allowed the team to systematically explore potential causes across four main categories:

1. Causes related to personnel,
2. Causes related to equipment,
3. Causes related to methods, and
4. Causes related to the working environment.

This structured approach considered the possible contributing factors and facilitate the identification of the root causes to guide targeted improvement actions.

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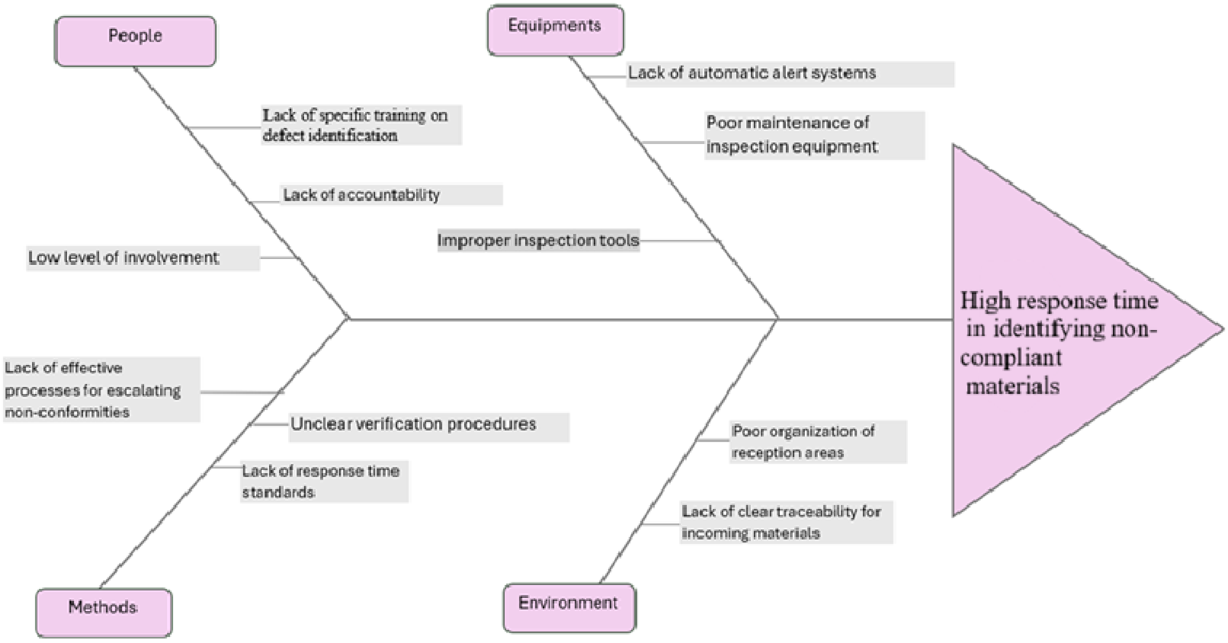

Figure 5. Ishikawa diagram for identifying possible causes of the determined problem

The Ishikawa diagram provided a structured visualization of the potential root causes, allowing them to be classified into four main categories:

- **Manpower – Human-related causes:** lack of specific training in defect identification, low employee engagement, and insufficient accountability within the inspection team.
- **Machine – Equipment-related causes:** use of inadequate inspection tools, absence of automatic alert systems, and poor maintenance of verification equipment.
- **Mother nature – Environmental causes:** inefficient organization of receiving areas and lack of clear traceability for incoming materials.
- **Method-related causes:** unclear inspection procedures, absence of standardized response times, and lack of effective escalation processes for nonconformities.

The decision to focus on only four M categories, rather than the traditional six, was based on the company's specific context. While theoretically including all six Ms could provide a more comprehensive view of factors affecting the process, in practice some aspects – such as management processes or measurement methods – were either too costly or difficult to modify relative to the expected benefits. Implementing major changes in these areas would have exceeded budget constraints and risked company resources. Therefore, the analysis was intentionally simplified to four Ms to focus on the factors with the greatest practical impact. This approach allowed the project team to direct efforts toward solutions that were both feasible and effective, ensuring meaningful improvements in the Incoming Material Inspection process without compromising financial or operational sustainability.

The potential causes identified through the Ishikawa diagram were further analysed using the 5Why method, which helps determine not only possible causes but also the true root causes of a problem, enabling the selection of solutions that address the core issue. All identified potential causes were incorporated into the 5Why analysis, as shown in Figure 6.

During this analysis, most of the causes from the Ishikawa diagram were examined. Exceptions either appeared indirectly through the decomposition of other causes or had no further underlying causes, making additional analysis unnecessary. The 5Why analysis revealed several root causes; however, the most frequently occurring and therefore the primary root cause was identified as the **lack of a standardized and efficient process for identifying and managing non-compliant materials**. This insight provides a clear focus for targeted improvement actions that will have the greatest impact on resolving the problem.

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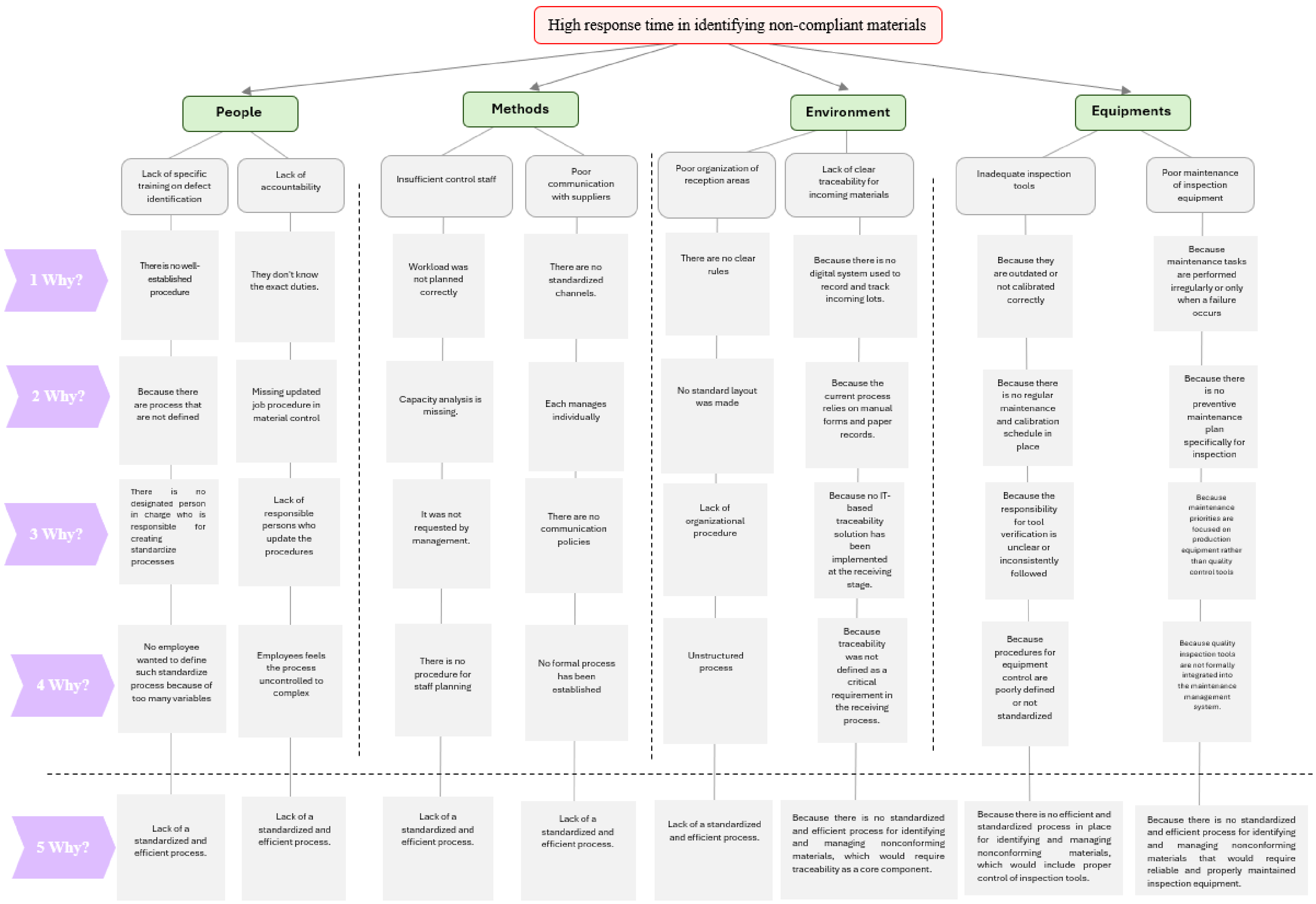

Figure 6. The 5Why's analysis

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Proceeding to the next stage of the methodology, finding the best improvement solution(s), the focus was on developing and implementing solutions that directly address the root causes identified in the previous phase (Sushmith, 2024). Ideas were generated using brainstorming sessions and by reviewing similar situations within the company, following established practices in large organizations. Insights were also drawn from Good Practice Reports and Lessons Learned Reports from industry leaders such as Toyota and Mercedes.

To ensure a comprehensive analysis, a centralized table (Table 2) was created. This table links each identified root cause to the corresponding proposed solution, assigns responsibility for implementation, and specifies the estimated implementation timeline. This structured approach facilitates accountability, ensures clarity of action, and allows for efficient monitoring of progress throughout the improvement project.

Table 2. Solutions identified for the root causes of the problem

ROOT CAUSE	PROPOSED SOLUTION	RESPONSABILE PERSON	DEADLINE
Lack of a standardized and efficient process	Develop and implement a standardized workflow for incoming material inspection, including clear guidelines, roles, and KPIs to ensure process consistency and efficiency.	Quality Manager	150 days
Because there is no standardized and efficient process for identifying and managing noncomplying materials, which would require traceability as a core component	Establish a traceability system integrated with a standardized nonconformity management process, enabling real-time tracking, escalation, and resolution of issues with incoming materials.	Quality Manager and IT Department	170 days

As shown in Table 2, most of the proposed solutions focused on improving the Incoming Material Inspection process or creating a more efficient version of it in various forms. Accordingly, the key improvement proposed for the primary problem – "Lack of a standardized and efficient process" – was the development of a fully documented process, as outlined in Table 2. The current process for 2024 is presented in Figure 10, while the improved process proposed in this study is detailed in Figure 11 below.

Following implementation, the project included ongoing monitoring to evaluate the effects of the solution. Throughout 2024, complaints from production regarding scraps and defective parts were recorded, alongside observations of changes in other types of complaints. This monitoring enabled the assessment of the impact of the new process on overall production quality and helped verify the effectiveness of the implemented improvements.

For the stage fifth of the DMAIC methodology, improving, the process improved are presented in Figure 10 and Figure 11 in the Results and discussion section.

The final stage of the DMAIC methodology, monitoring the changes made, focuses on tracking the implemented improvements, sustaining progress, and preventing regression to previous conditions. Key activities in this stage include monitoring the system and effectively communicating the changes to all relevant stakeholders (Sushmith, 2024). In line with this, the monitoring of complaints recorded throughout 2024 is summarized in Table 3, providing a clear view of the impact of the implemented improvements on the Incoming Material Inspection process and overall production quality. Additionally, key stakeholders, including the Quality Department Manager and Production Managers, were informed about the implementation of this improvement plan to ensure alignment and support for enhancing organizational performance.

Table 3. Qualitative and quantitative sorting of complaints registered in 2024

	January	February	March	April	May	June	July	August	September	October	November	December	**TOTAL**
Non-retrievable items	3	9	12	13	12	16	10	6	5	5	10	10	**85**
Retrievable items	3	0	3	5	8	9	0	1	3	6	5	7	**50**
Labeling Issues	3	0	3	5	8	9	0	2	5	10	9	7	**59**
Color/appearance not in compliance	5	6	8	5	9	2	6	3	7	4	5	5	**65**
Out of stock/shortage	8	7	9	5	3	7	6	4	5	8	6	6	**74**
Material quality issues	5	6	8	5	9	2	6	3	7	4	5	5	**65**
Contamination or dirt	9	6	8	7	10	9	2	5	9	8	6	4	**83**
TOTAL	**36**	**34**	**51**	**45**	**59**	**54**	**30**	**24**	**41**	**45**	**46**	**44**	

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3. Results and discussion

The results of this study are reflected in the performance status of the defined indicators, which were continuously monitored throughout 2024. These measurements demonstrate the sustained progress achieved following the implementation of the improvement project. In addition, the newly developed and optimized process itself represents a significant outcome of this research, providing a more efficient and standardized approach to incoming material inspection. The evolution of the key performance indicators is illustrated in the figures below (Figures 7, 8 and 9), highlighting the positive impact and consistency of the improvements over time.

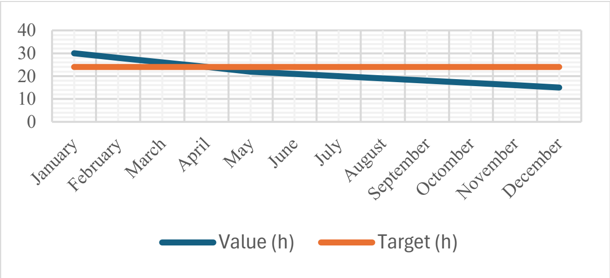

Figure 7. The current response times to the identification of non-compliant materials

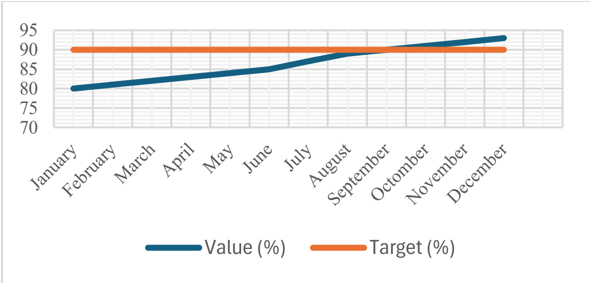

Figure 8. The number of cases resolved in less than 24 hours

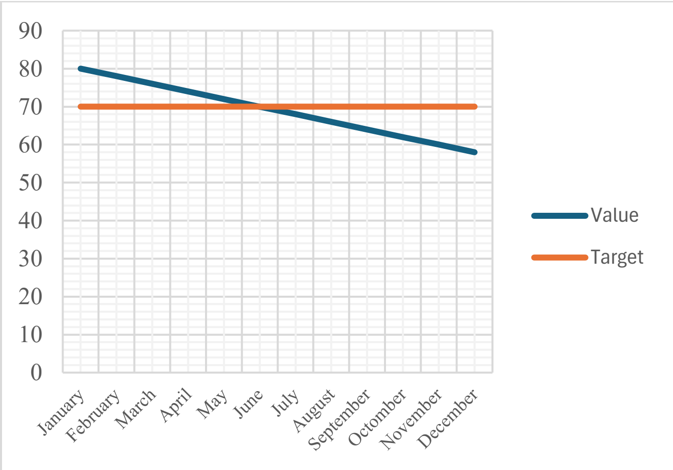

Figure 9. The number of recurring non-compliances in 2024

Figure 7 illustrates a consistent monthly reduction in the measured time (hours), decreasing from 30 hours in January to 15 hours in December. This downward trend represents a substantial improvement compared to the established target of 24 hours. Although the target was slightly exceeded during the first three months, from April onward all recorded values remained at or below the desired threshold. This consistent performance demonstrates the effectiveness and sustainability of the implemented improvement measures, confirming that the actions taken successfully reduced processing time and stabilized the process throughout the year.

Figure 8 shows a steady month-over-month increase in performance, improving from 80% in January to 93% in December. Although the target value of 90% was not reached during the first eight months, it was achieved in September and subsequently exceeded in the following months. This upward trend demonstrates the positive impact of the implemented improvement actions, reflecting a consistent and sustained enhancement in process performance over the year. The results confirm that the corrective measures applied were effective in driving progress and maintaining performance above the established target.

Figure 9 illustrates a continuous decline in monthly values, decreasing from 80 in January to 58 in December, while the target remained constant at 70. The target was first met in June; however, from July onward, the results consistently fell below the target and continued to decline through the end of the year. This downward trend suggests the emergence or escalation of performance issues, resource limitations, or process inefficiencies. To address these deviations, further analysis is recommended to identify root causes and implement corrective actions aimed at restoring and stabilizing performance at the desired level.

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As shown in Table 2, most of the identified solutions focused on improving the Incoming Material Inspection process or developing a new, more efficient version of it in various forms. Accordingly, the proposed improvement for the problem addressed is the creation of a documented and standardized process, aligned with the program outlined in Table 2, specifically in the section addressing the *"Lack of a standardized and efficient process."* The current process, reflecting the state of operations in 2024, is presented in Figure 10, while the proposed improved process developed in this study is detailed in Figure 11.

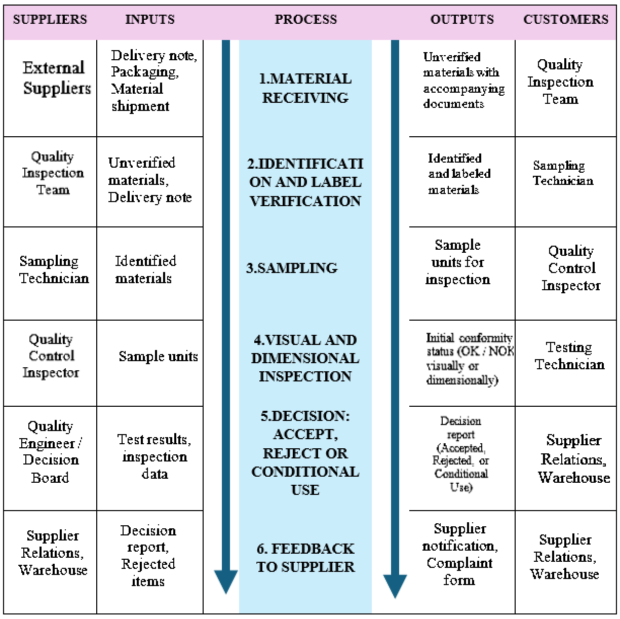

Figure 10. The current process for the year 2023

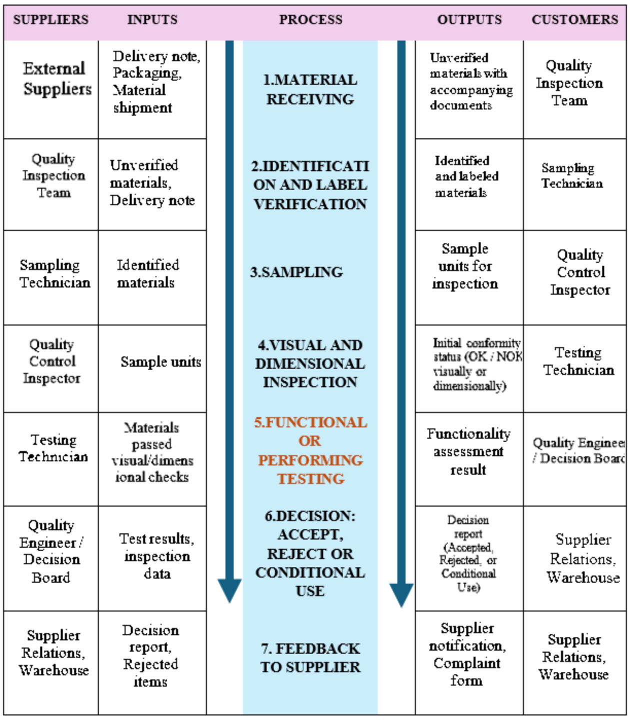

Figure 11. The improved process for the year 2024

The implementation of the improvement project generated significant results in the performance of the Incoming Material Inspection process within the automotive industry. Through the structured application of the DMAIC methodology, measurable progress was achieved and closely monitored at each stage. The initial analysis of performance indicators identified inefficiencies related to inspection time, defects detection accuracy, and the consistency of supplier evaluation criteria. After defining the root causes, targeted solutions were implemented, including the redesign of the Incoming Material Inspection process. As a result, the average inspection time per delivery decreased considerably, enabling faster material processing and improved workflow efficiency. The defects detection rate also increased, reflecting enhanced process control and quality assurance. Overall, the application of DMAIC led to a more transparent, standardized, and efficient inspection system. The objectives established at the start of the project were fully met and, in several cases, exceeded – demonstrating both the effectiveness of the implemented measures and the value of cross-functional collaboration. The improvements achieved confirm the strategic importance of continuous improvement initiatives at this stage of the supply chain and underscore their positive impact on organizational performance and competitiveness.

4. Conclusion

This study demonstrated the effectiveness of applying the DMAIC methodology to optimize the Incoming Material Inspection process in the automotive industry. By systematically addressing root causes and implementing targeted improvements, the project achieved measurable and significant results: the average response time to identify non-compliant materials was reduced from 48 hours to 15 hours, surpassing the initial target of 24 hours; compliance with the 24-hour resolution target increased from 60% to 93%, and recurring non-conformities decreased by 27% compared to the baseline. These improvements not only accelerated corrective actions but also enhanced process transparency, supplier accountability, and overall production stability.

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The originality of this research lies in its integration of DMAIC with automotive logistics, providing empirical evidence that structured quality tools can deliver rapid, quantifiable gains in a highly complex supply chain environment. Unlike prior studies that focused primarily on assembly or production lines, this work addresses a critical upstream process – material inspection – where delays propagate through the entire value chain. By presenting a validated framework supported by concrete performance metrics, this paper contributes to applications in automotive logistics and offers a replicable model for similar contexts.

Strategically, the findings underscore that improving responsiveness and traceability in material inspection is not merely an operational enhancement but a competitive imperative. Faster response times and standardized workflows strengthen resilience against supply disruptions, reduce waste, and support sustainability objectives by minimizing resource losses. This approach can be generalized across other automotive processes and extended to adjacent industries, positioning organizations to meet the dual challenge of operational excellence and environmental responsibility. In an era where agility and sustainability define market leadership, structured methodologies like DMAIC represent a cornerstone for long-term competitiveness in the automotive sector.

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