

## EQUIPMENT BREAKDOWN VISUALIZATION: A CASE STUDY IN AUTOMOTIVE MANUFACTURING PLANT

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**Abstract.** In the body shop production of automotive manufacturing, automated production systems play a critical role, since equipment reliability plays a major role in production flow and performance. Many manufacturing plants have breakdown data available, however, overall maintenance decision-making is still reactive, due to manual data recording and poor analytical capability. This study investigate the current system of equipment breakdown data management used in an automotive body shop and suggesting a dashboard-based visualisation approach to enable maintenance action plan. A qualitative case study was used using interviews, observation and document analysis as data collection method. Results show that maintenance activities was carried out manually using spreadsheet-based logs of data which limited the analysis of historical trend, critical equipment identification, and recurring failure patterns. As a suggestion, a breakdown dashboard was created to consolidate breakdown data and visualize the main maintenance statistics such as total equipment downtime, breakdown frequency, machine-based comparison, time-based trend, breakdown classification by type of problem, and total breakdown cases. The results indicate that the dashboard visualisation enhances the visualization of breakdown and provides the basis for more structured decision-making during maintenance activity. This research also suggests the need for training and continued use of dashboard as a part of maintenance work, for successful long-term maintenance.

**Keywords:** *automotive manufacturing, equipment, breakdown, maintenance, dashboard*

### Introduction

The manufacturing industry contributes to economic growth, productivity gain and enhanced industrial competitiveness through manufacturing processes that transform raw material to product with a structured production system (Dubey et al., 2024). The manufacturing industry contributes significantly to global GDP and employs millions of people, and is also considered one of the important driving forces of the economy (Costa et al., 2024). In Malaysia, manufacturing contributes approximately 23% of the national GDP through various economic activities, and the automotive industry is regarded as one of the strategic sectors which fuels industrialisation and technological progress (Lemya, 2025). Automotive production has a large capital intensity, relies on significant levels of automation together with high technology production systems and heavy use of equipment and machinery (Aripin et al., 2024). Within this automotive manufacturing industry, the body shop operations are primarily supported by automated welding systems, jigs, robots, and handling equipment to maintain high-volume and continuous production (Kovarikova et al., 2023). According to Ojeda et al. (2025), poor maintenance strategies reduces plant's overall productive capacity by 5% to 20%, and

unplanned downtime is costing industrial manufacturers approximately USD 50 billion annually. With the high dependency of automation, the management of equipment maintenance becomes crucial to sustain competitiveness in modern automotive manufacturing environments (Ojeda et al., 2025; Tortorella et al., 2021).

As most processes in the automotive manufacturing are driven by machines and are tightly sequenced, production performance is highly dependent on the reliability and continuous operation of equipment (Zehra et al., 2024). The equipment, like welding controllers, robotic systems, jigs, and material handling units, work in an interdependent manner, making a machine failure in one unit stop the entire production line (Kovarikova et al., 2023). According to Ojeda et al. (2025), any issues relating to the equipment are responsible for about 60–70% of the unplanned downtime in automotive manufacturing, and therefore, body shop operations are one of the most affected due to the high levels of automation employed. To mitigate these threats, organisations commonly implement traditional maintenance practices such as reactive maintenance, where the action is only taken once a failure happens, followed by preventive maintenance that includes scheduled inspection and servicing (Kovarikova et al., 2023; Lee et al., 2020). However, it has been demonstrated that reactive maintenance may still represent more than 40% of maintenance work in numerous manufacturing plants (Ahern et al., 2022).

Despite the development of advanced manufacturing technologies, the maintenance management in many automotive manufacturing areas seems to lag in data utilisation and decision support (Rosati et al., 2023). Conventional maintenance methods for preventive and reactive maintenance are still popular and are, in some cases, increased by disconnected or manually managed data systems (Ahern et al., 2022). Although research emphasised predictive maintenance and digital transformation, there has been limited focus on the visualisation and potential to operationalise breakdown data to support maintenance planning. Practically, breakdown data is often recorded manually or in basic spreadsheets, restricting the ability to analyse historical trends, identify recurring failures, and prioritise maintenance actions effectively (West et al., 2024). This situation makes maintenance operations less efficient and reduces proactive control over production flow and equipment performance. Hence, there is a gap in understanding how practical visualisation tools can bridge the gap between available breakdown data and effective maintenance decision-making in automotive manufacturing settings.

This study was conducted at an automotive manufacturing firm (Company A) involving automotive manufacturing operations. Body operation is one of the main operation shops that involves highly automated equipment, including welding systems, jigs, robots, lifters, and riveting. Company A has recurring equipment breakdowns that disrupt production flow and require frequent maintenance intervention. While breakdown information is routinely recorded, without a visual monitoring system, it is difficult for maintenance staff and management to clearly identify breakdown patterns, dominant problem areas, and equipment priorities. Therefore, the maintenance operations are mostly reactive and based on subjective experience rather than systematic analysis. This practical context highlights a detailed information handling procedure for breakdown data management, which improvement on visualization could help better planning, and more informed maintenance decision-making.

By addressing limitations in the management and utilisation of equipment breakdown data, this study aims to improve maintenance planning and decision-making

in an automotive body shop. This study specifically aims to identify the visualisation of breakdown information to improve visibility of breakdown trends, recurring failures, and equipment performance. With a structured visualisation approach, this study aimed to help in making more informed maintenance decisions and to reduce reliance on reactive maintenance practices in the company. Specifically, the objectives of the study are: (1) To assess the current practices of recording and managing equipment breakdown data in an automotive body shop; and (2) To propose a visualisation approach for monitoring equipment breakdowns to support effective maintenance planning in the case company.

This study contributes to current literature from a practical as well as scholarly perspective. From an industrial perspective, the results help maintenance and management organisations get better visibility on equipment breakdown information, help identify critical equipment and recurring failures, and allow them to prioritise maintenance efforts accordingly. The proposed visualisation helps practitioners in making more informed and timely maintenance decisions, reducing reliance on reactive actions and better facilitating production flow in automotive body shop operations. Theoretically, this study contributes to the maintenance management and manufacturing literature by demonstrating that data visualisation can help provide practical information that supports decision-making. It advances existing discussions on maintenance strategies by focusing on how breakdown data can be transformed into actionable insights within real industrial settings.

## *Literature review*

### *Automotive manufacturing industry*

The automotive manufacturing industry has been widely discussed in the literature due to its complex production structure, high production volumes, and stringent quality requirements (Caliskan et al., 2022). Automotive manufacturing is characterised by a highly integrated system in which multiple production stages operate in a tightly coordinated sequence to ensure stable production flow (Khan and Hasan, 2023). Such processes are in sequence, making automotive production systems particularly sensitive to disruptions, and delays or failures can ultimately lead to operational losses and disturb overall plant performance (Aripin et al., 2023; Ding et al., 2023). To remain competitive, automotive manufacturers emphasise efficiency, consistency, and operational reliability, with production systems commonly designed for continuous operation and limited tolerance for variation (Silva and Gomes, 2023). Moreover, manufacturing requires automation, especially in automotive manufacturing that has high-throughput production settings (Zhou et al., 2023). Robotics, automated welding systems, and specialised fixtures are commonly used to optimise production effectiveness and product quality (Aripin et al., 2023). Yet, the growing amount of automation also increases risk and reliance on the performance of equipment, as a result, the production lines of new technology operate with very little buffer capacity (Lee et al., 2020). According to Rosati et al. (2023), equipment breakdown causes production delays, stops production, and increases operating costs. As a result, proper maintenance of equipment performance is also repeatedly perceived as one of the most significant requirements for maintaining production stability as well as operational efficiency in automotive production (Zhou et al., 2023).

### ***Body shop operations in automotive manufacturing***

The body shop process is an important step in automotive manufacturing due to its critical role in forming the vehicle body structure and support for downstream production processes (Chuenmee et al., 2025; Stauder and Kühn, 2022). According to Chuenmee et al. (2025), the body shop is a highly automated stage of production, with panel positioning, clamping, and welding of the body work steps resulting in a rigid and accurate representation of the dimensions of vehicle bodies. Jigs, fixtures and digital welding systems allow for homogeneous production yet high dependency through production of multiple workstations (Liu et al., 2024). As noted by Utku (2023), the highly ordered nature of body shop operations, in such a manner, any disturbance in one of the stations can influence all the production lines, which has an impact on production system flow and productivity.

Accordingly, the higher automation level that body shop operation requires dependence on specialist equipment and a combined control system. Robotic welding systems, welding controllers, and sensor-based monitoring devices run in a continuous, low buffer capacity process, with a corresponding reduction in operational flexibility during the failure of critical equipment (Çetin and Demirci, 2024). Breakdown failure in body shop equipment will typically lead to line stoppages, rework, and production delay, causing considerable loss in production efficiency (Çetin and Demirci, 2024; Roberts and Cullinane, 2023). Also, repetition and high mechanical load levels expose body shop equipment to wear, improper alignment, and electrical malfunction (Roberts and Cullinane, 2023). Thus, making it clear that body shop is one of the most maintenance-intensive processes of automotive manufacturing, hence highlighting the need for efficient maintenance management in the manufacturing process.

### ***Maintenance management in automotive manufacturing***

Maintenance management has been extensively investigated in the automotive manufacturing industry due to the industry's dependence on automated and interconnected production systems (Roberts and Cullinane, 2023). Discrete and continuous production are the key features of an automotive plant in which equipment availability depends on productivity, delivery performance, and cost efficiency. According to Kovarikova et al. (2023), maintenance activities are important to maintain the flow of production, especially in the body shop operations where welding systems, robots, and jigs work in tightly sequenced processes. According to West et al. (2024), ineffective maintenance management can result in frequent unplanned downtime and a decrease in the overall equipment effectiveness of manufacturing systems. Similarly, Roberts and Cullinane (2023) highlighted as automation levels increase in automotive plants, maintenance strategies should be carefully managed to avoid disruptions that can spread across multiple production stages. In this perspective, automotive manufacturers must regularly employ corrective and preventive maintenance strategies to ensure equipment reliability and operational stability.

### ***Corrective maintenance***

Corrective maintenance is a maintenance action performed after equipment failure to restore the equipment to its normal operating condition (Mołęda et al., 2023). Bhattacharjee and Roy (2025) found that unexpected failures of welding equipment, robotic systems, and jigs frequently result in line stoppages, requiring immediate

corrective intervention. According to Mołęda et al. (2023), corrective maintenance in automotive plants is often associated with higher downtime duration and increased maintenance costs due to emergency repairs and production interruptions. Corrective maintenance, although facilitating rapid recovery of failed equipment, has some limitations, such as limited root cause analysis and repeated failure occurrences (West et al., 2024). Consequently, excessive reliance on corrective maintenance can adversely impact production stability and maintenance efficiency in automotive manufacturing operations.

### ***Preventive maintenance***

Preventive maintenance involves planned and scheduled maintenance activities intended to reduce the likelihood of equipment failure (Erbiyik, 2022). In automotive manufacturing, preventive maintenance is widely implemented for critical body shop equipment such as welding guns, robotic arms, jigs, and material handling systems. Pohan et al. (2023) reported that scheduled inspections, routine servicing, and component replacement are commonly used to improve equipment reliability and reduce unexpected breakdowns. Preventive maintenance has been shown to support more stable production performance when properly executed. However, several studies have highlighted limitations of preventive maintenance practices in automotive plants. (Mołęda et al., 2023) noted that preventive maintenance schedules are often time-based and developed without sufficient analysis of historical breakdown data. Consequently, recurring equipment failures may persist despite regular preventive activities, indicating the need for better utilisation of breakdown information to support maintenance planning.

### ***Breakdown performance monitoring***

The analysis of breakdown data in maintenance and manufacturing is a useful tool for guiding planning and decision-making on systematising maintenance (Hinrichs et al., 2024). As manufacturing systems become increasingly automated and interconnected, Raoufi et al. (2024) highlight that raw breakdown records alone are insufficient to provide meaningful insights into equipment performance. Lu et al. (2023) suggest that poor data management of breakdown data may hinder organisational capability in understanding failure behaviour, recognising repeating problems, and improving maintenance. As a result, Sharma et al. (2024) highlight that structured approaches that support interpretable breakdown information are crucial to facilitate better understanding and to support maintenance decisions in complex manufacturing contexts.

### ***Total equipment downtime***

Total equipment downtime is identified as a critical indicator of maintenance performance and production loss. Zehra et al. (2024) reported that excessive downtime in automotive manufacturing is closely linked to reduced overall equipment effectiveness and disrupted production flow. Similarly, Al-Duais et al. (2022) highlighted that cumulative downtime provides better insight into maintenance effectiveness than individual breakdown events. Additionally, analysing total downtime over time allows organisations to identify performance issues and evaluate the impact of maintenance actions.

### ***Breakdown frequency***

Reliability of equipment breakdown is represented by the total breakdown cases. Madhav et al. (2023) observed that high breakdown frequency in the automotive manufacturing process involves repetitive failure modes that are not adequately addressed through routine maintenance. Observing breakdown rates helps maintenance teams to differentiate between failures and systematic equipment problems, which lead to clearer maintenance planning (Karim, 2025).

### ***Machine-based breakdown comparison***

Previous researchers highlight the importance of analysing the breakdown performance of different machines to find critical equipment. Shahin et al. (2023) pointed out that a small number of machines often contribute disproportionately to overall downtime in manufacturing systems. In the automotive manufacturing industry, Madhav et al. (2023) noted that machine breakdown analysis facilitates prioritisation of maintenance resources by focusing on high-impact equipment. Comparing machines on breakdown frequency and contribution to downtime allows for more targeted maintenance and better allocation of resources (Chuenmee et al., 2025).

### ***Time-based breakdown and downtime trends***

The literature does use a time-based analysis of breakdown data for assessing maintenance performance over time. Karim (2025) identified that visualising downtime trends across production periods enables organisations to determine whether maintenance actions result in performance uplift. Similarly, Al-Duais et al. (2022) pointed out that regular peaks in the trend of downtime frequently mean that there are failure mechanisms that have not been resolved. The ability to track dynamic changes of performance with trend analysis will enable maintenance teams to detect periods in which abnormal behaviour occurs and aid in continuous maintenance improvement.

### ***Breakdown classification and root cause analysis***

The classification of breakdowns by problem type or root cause is frequently emphasised in maintenance literature as a means of supporting permanent corrective actions. Mołęda et al. (2023) highlighted that understanding recurring failure causes is essential for moving beyond repeated corrective maintenance. Kang et al. (2022) pointed out that breakdown classification allows to detect failure that contribute to recurring production breakdowns. Organisations can then focus on long-term improvement measures for breakdowns by root cause analysis, instead of repeating the short-term measures.

## **Materials and Methods**

This research uses a qualitative case study method to understand how breakdown data management practices and visualisation contribute to maintenance planning in an automotive body shop setting. According to Yin (1994), a qualitative research design is suitable as the study focuses on understanding real maintenance practices, challenges, and decision-making processes within their operational context rather than testing

hypotheses or measuring causal relationships. The case study approach is used to explore breakdown handling and data use in an automotive manufacturing organisation in detail, where equipment performance, maintenance activities, and data utilisation are related. Yin (1994) states that case studies are relevant to investigating contemporary phenomena within real-life settings when contextual factors play a significant role. This methodological approach enables the researcher to gain detailed insights into existing breakdown practices and provides a strong foundation for developing a dashboard-based visualisation aligned with practical maintenance needs.

### ***Case company***

The case company selected for this study (Company A) is an automotive manufacturing organisation operating within a highly automated production environment. The study focuses on the body shop section, which is a critical stage in the vehicle production process and relies extensively on specialised equipment such as welding systems, jigs, and material handling devices. Body shop operations in Company A are sequenced processes and continuous production requirements, where equipment performance directly affects production flow. Maintenance activities are routinely conducted to support operational continuity. However, equipment breakdowns still occur and require timely intervention. Breakdown information is recorded as part of daily operational practices and is used to support maintenance actions and reporting. This case company was selected due to its relevance to the research objectives and its suitability for examining breakdown data management and visualisation practices within a real industrial setting.

### ***Data collection methods***

This study employs multiple data collection methods to obtain a comprehensive understanding of equipment breakdown data management and maintenance practices in the case company. Data were collected through semi-structured interviews, observations, and document analysis to capture both reported practices and actual operational conditions within the automotive body shop environment. The use of multiple data sources enables data triangulation, which enhances the credibility and robustness of qualitative research findings (Creswell et al., 2011). A convenience sampling technique was adopted for the selection of the case company and informants. The case company was selected based on its relevance to the research objectives and its operation within an automotive manufacturing body shop. Informants were selected from personnel directly involved in maintenance and production activities, including those responsible for equipment performance and breakdown management.

### ***Interviews***

Semi-structured interviews were conducted to obtain in-depth insights into current maintenance practices, breakdown handling procedures, and challenges related to breakdown data management. This interview approach allows flexibility to explore key issues while maintaining consistency across informants (Yin, 1994). Informants were selected from personnel directly involved in maintenance and production activities, including roles related to equipment maintenance, supervision, and production support. The interviews focused on how breakdown information is recorded, how maintenance decisions are made, and the extent to which breakdown data are analysed and used for

planning purposes. The semi-structured format enabled the researcher to probe relevant issues that emerged during the discussion while ensuring that the information collected was aligned with the research objectives.

### ***Observation***

Direct observation was performed to observe actual maintenance practices and breakdown in the automotive body shop for an accurate record of actual maintenance practices and breakdown handling operations in the automotive body shop. Researchers can observe the real operational behaviour and practices that may not be fully explained through interviews alone (Creswell et al., 2011). During on-site observation, the researcher observes how the information on breakdown was recorded, how communication occurred between production and maintenance personnel, and how maintenance actions were prioritised. This process allowed for practical access to actual working practice in the field and verification of the information gathered from interviews.

### ***Document analysis***

Document analysis was used to review existing records related to equipment breakdowns and maintenance activities in the case company. Documents examined included breakdown logs, maintenance reports, and spreadsheet-based records used for tracking equipment failures. Document analysis is commonly used in qualitative case studies to complement interview and observation data and to provide objective evidence of organisational practices Yin (1994). Reviewing these documents enabled the researcher to understand the type of breakdown data recorded, the level of detail captured, and how historical information was stored and accessed. Information obtained from document analysis was used to support triangulation and to inform the selection of key indicators for dashboard visualisation.

### ***Analysis method***

Data analysis of this study was performed in a systematic qualitative approach to integrate the gathered data based on interviews, observations, and document analysis. Interview data were examined for recurring issues of breakdown data recording, maintenance practices, and decision-making. To validate and corroborate interview findings, observational data were measured by comparing reported practices to actual shop-floor activities. Document analysis was conducted to explore the structure and usability of current breakdown records. Following that, the collected data was compared and analysed to identify the problems of breakdown data and relevant breakdown indicators. The data analysed was used to identify the dashboard requirements and key performance indicators, as well as visualisation, ensuring that the developed dashboard can reflect both practical requirements and insights derived from the case study.

### ***Dashboard development process***

In this study, the dashboard development process was guided by the literature review results and the findings from the case study. Based on issues identified in breakdown data management practices, relevant breakdown indicators were first determined to ensure alignment with maintenance planning needs. These indicators were selected

based on the commonly reported maintenance metrics from the literature, including equipment downtime, breakdown frequency, machine-based breakdown contribution, time-based trends, and breakdown classification by problem type. The selection process focused on indicators that provide clear visibility of breakdown conditions, which could assist decision-making in maintenance from both operational and managerial levels. After identifying indicators, breakdown records from document analysis were used as the basis for analysis and prepared in accordance with the need for visualisation. Data was grouped and formatted to ensure consistency and usability for dashboard implementation. A dashboard using Power BI software was applied to convert the chosen indicators into visual elements like charts, key performance indicators and filtering capabilities. The visualisation was designed with a focus on clarity, simplicity and understanding to ensure users will be able to quickly interpret breakdown conditions and identify areas of priority for maintenance intervention. The end product dashboard serves as a decision-support tool to increase the visibility of the breakdown data for more structured maintenance planning. The final product was presented to the management team of Company A for validation, feedback and confirmation of its practicality in supporting maintenance decision-making and planning activities.

## Results and Discussion

The breakdown data in the automotive body shop were hand-recorded in Microsoft Excel after the end of each production shift, as shown in *Table 1*. Every single record had basic information such as equipment name, downtime duration, breakdown description, corrective action taken, and machine status, and was saved in different spreadsheet files. While this enabled documentation of breakdown events, the data were not structured for integrated analysis. Consequently, maintenance personnel struggled to find repeated breakdown patterns, critical machines, and prevalent problem types. The breakdown prioritisation was mostly reactive which the maintenance actions were performed with an emphasis on the reestablishment of production flow and not an investigation of the root cause. An absence of structured summaries, including total downtime or machine-level breakdown comparison, limited visibility on overall maintenance efficacy and reduced effectiveness of maintenance planning, caused a heavy dependence on experience-based decision making.

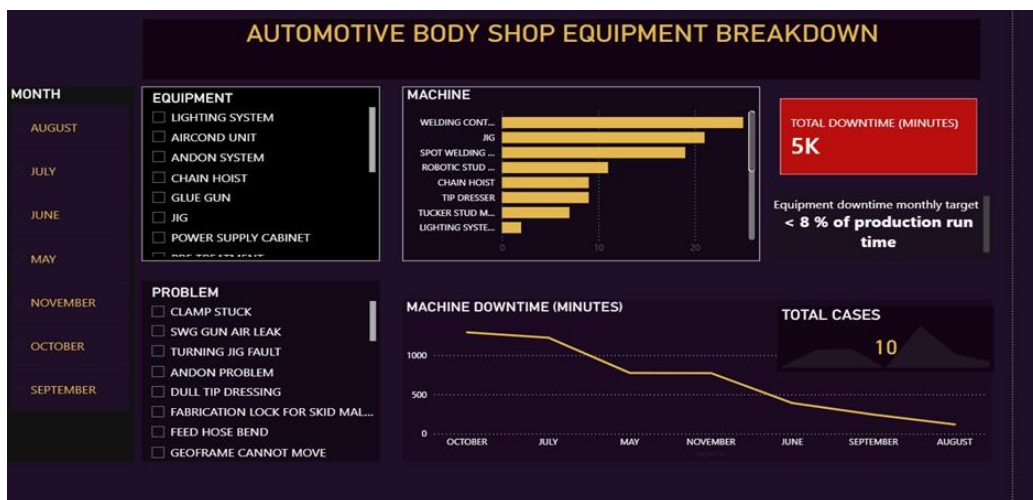
**Table 1.** Example of breakdown data record in spreadsheet format.

M	DO	DC	E	B	L	T	P	A	MD	S	PIC
MAY	7/5/2025	15/5/2025	PRE TREATMENT	PRE TREATMENT	PRE TREATMENT	BREAK DOWN	MCCB HEATER TRIP	1) REPLACE MCCB HEATER NO.3, TEST OK	30	CLOSED	FARIS
MAY	7/5/2025	7/5/2025	CHAIN HOST	MRA2	STN 6150	BREAK DOWN	UNABLE TO LIFT	1) VERIFY THE REPLACE CUTTER	5	CLOSED	FARIS
MAY	15/5/2025	17/5/2025	TIP DRESSER	MRA2	STN 6410	BREAK DOWN	DULL TIP DRESSING	REPLACE CUTTER BLADE (59213415) IPC	10	CLOSED	ZAFARI
MAY	15/5/2025	7/6/2025	LIGHTING SYSTEM	MRA2	STN 6411	BREAK DOWN	LAMP MALFUNCTION	CHANGE THE REPLACE TIP DRESSING	700	CLOSED	FARIS
MAY	17/5/2025	20/5/2025	TIP DRESSER	MRA2	STN 6040	BREAK DOWN	DULL TIP DRESSING	REPLACE TIP DRESSING	30	CLOSED	FARIS
JUNE	10/6/2025	10/6/2025	POWER SUPPLY CABINET	PRE TREATMENT	PRE TREATMENT	BREAK DOWN	MCCB POWER SUPPLY TRIP	1) VERIFY THE PROBLEM, FOUND	10	CLOSED	FARIS
JUNE	11/6/2025	11/6/2025	SPOT WELDING GUN	MRA2	STN 6392	BREAK DOWN	SWG GUN DAMAGED	1) VERIFY THE	25	CLOSED	FARIS
JUNE	11/6/2025	11/6/2025	CHAIN HOST	PRE TREATMENT	PRE TREATMENT	BREAK DOWN	UNABLE TO LIFT	1) VERIFY THE PROBLEM, FOUND	20	CLOSED	FARIS
JUNE	13/6/2025	13/6/2025	CHAIN HOST	PRE TREATMENT	PRE TREATMENT	BREAK DOWN	UNABLE TO LIFT	1) VERIFY PROBLEM, CHECK TRAVELER	60	OPEN	FARIS
JUNE	14/6/2025	14/6/2025	ANDON SYSTEM	MRA2	ALL STATION	BREAK DOWN	ANDON PROBLEM	1) VERIFY THE	40	OPEN	FARIS
JUNE	10/6/2025	14/6/2025	GLUE GUN	MRA2	STN 6030	BREAK DOWN	GLUE STUCK	1. ADD 1 SET OF GLUING	40	CLOSED	FARIS
JUNE	14/6/2025	14/6/2025	CHAIN HOST	MRA2	STN 6391	BREAK DOWN	UNABLE TO LIFT	1. VERIFY THE	20	CLOSED	FARIS
JUNE	15/6/2025	15/6/2025	JIG	MRA2	STN 6120	BREAK DOWN	CLAMP STUCK	1. VERIFY THE	18	CLOSED	FARIS
JUNE	15/6/2025	15/6/2025	SPOT WELDING GUN	MRA2	STN 6030	BREAK DOWN	SWG GUN DAMAGED	1. VERIFY THE	5	CLOSED	FARIS
JUNE	15/6/2025	15/6/2025	JIG	MRA2	STN 620	BREAK DOWN	CLAMP STUCK	1. VERIFY THE	5	CLOSED	FARIS
JUNE	15/6/2025	15/6/2025	SPOT WELDING GUN	MRA2	STN 6020	BREAK DOWN	SWG GUN DAMAGED	1. VERIFY THE	5	CLOSED	FARIS

Note: M=Month, DO=Date Open; DC=Date Closed; E=Equipment; B=Building; L=Location; T=Type; P=Problem; A=Action; MD=Machine Downtime; S=Status.

### Dashboard visualisation results

Based on the breakdown data consolidated from spreadsheet records, a dashboard was developed to visualise equipment breakdown performance in the automotive body shop, as shown in *Figure 1*. The dashboard integrates key breakdown indicators into a single interface to improve visibility of maintenance performance and support structured maintenance decision-making. The developed dashboard integrates several indicators, which include: (1) Equipment and Month Selection: The dashboard includes selection functions based on equipment type and month. These functions allow users to filter breakdown data according to specific machines and time periods. This supports focused analysis by enabling maintenance personnel to examine breakdowns during selected months without reviewing multiple raw data files. (2) Machine-Based Breakdown Frequency: Breakdown frequency is visualised by the machine using a bar chart. This visualisation highlights equipment that records the highest number of breakdown occurrences. The results indicate that certain machines contribute more significantly to breakdown cases compared to others. This information supports the identification of critical equipment and helps prioritise maintenance actions.



*Figure 1. Breakdown dashboard for automotive body shop equipment.*

(3) Total Equipment Downtime: Total equipment downtime is displayed as a key indicator representing the cumulative downtime caused by breakdowns within the selected period. This indicator provides a direct measure of production impact and allows maintenance personnel to assess whether downtime remains within acceptable limits based on predefined performance targets. (4) Time-Based Downtime Trend: The dashboard presents downtime trends across different months using a line chart. This visualisation enables evaluation of maintenance performance over time. A decreasing trend reflects improvement in breakdown control, while recurring peaks indicate unresolved breakdown issues that require further investigation. (5) Breakdown Classification by Problem Type: Breakdowns are classified based on problem type, such as clamp issues, air leaks, or equipment faults. This classification highlights dominant failure categories affecting body shop operations. By identifying recurring problem types, maintenance teams can focus on permanent corrective actions rather than repeated reactive repairs. (6) Total Breakdown Cases: The total number of breakdown

cases is displayed as a summary indicator. This indicator provides a quick overview of breakdown frequency within the selected period. When considered together with total equipment downtime, it helps distinguish between frequent minor breakdowns and fewer but more severe breakdown events.

## **Conclusion**

It is concluded that good breakdown data management is key to aiding maintenance planning in highly automated automotive body shop operations. The findings of this study demonstrate the constraints of historical trend analysis, critical equipment identification, and persistent type analysis in using manual and spreadsheet breakdown records. Divided data storage decreases overall visibility of maintenance performance and promotes reactive, experience-based decision-making. As such, this work provides an overview that centralisation of breakdown data into a better visualisation helps to systematically monitor crucial maintenance metrics, such as downtime, breakdown frequency, machine-based comparison, and problem classification, can be monitored in a more structured manner. The dashboard helps in gaining clearer insight into the equipment performance and production impacts, as well as aiding the systematic analysis of maintenance conditions. Overall, the study confirms that visualisation of breakdown data provides meaningful insights that are difficult to obtain from raw records alone, and highlights the value of structured visual tools in improving maintenance monitoring and planning in automotive body shop manufacturing. Additionally, the findings emphasise the need for training and capability strengthening in ensuring effective use of the breakdown dashboard. The dashboard delivers clear visual information, and maintenance team members and supervisors must be able to analyse data closely to take the insights and act in real time. Without the proper training, the dashboard risks being used only as a reporting tool rather than as a decision-support tool. Consequently, it is necessary to have regular training programmes in dashboard interpretation, performance indicators, and maintenance prioritisation to develop the data-driven maintenance capacity. Training also ensures even use of the dashboard across shifts and personnel, reducing the reliance on personal experience. It was found that structured training and user-friendly guidelines to integrate the dashboard and its application into regular maintenance efforts are essential so that the dashboard may serve as a continuous tool instead of being an isolated aspect of daily and periodic maintenance activities.

Furthermore, sustaining the dashboard as a routine maintenance practice is key to the long-term effectiveness of this tool. It implies that this dashboard must be nested within the existing maintenance workflow, such as daily production meetings, weekly maintenance reviews, and continuous improvement discussions. Maintaining the tool takes up top management commitment, regular updates of data, and continuous reassessment of the dashboard's pertinence. While the existing dashboard is built from historical breakdown data, the research also suggests potential areas of improvement through the integration of digital technology, such as Internet of Things (IoT) sensors and automated data collection systems. Integration with IoT-enabled equipment may provide real-time or near real-time monitoring of breakdown conditions, to support and optimise a gradual transition towards more proactive maintenance strategies. From a practical viewpoint, this study presents maintenance personnel and management with a straightforward and practical procedure for enhancing utilization of breakdown data

through existing data sources. The dashboard presents a systematic way to see breakdown information without requiring advanced predictive technologies or major system investments. By presenting detailed information on downtime impact, breakdown frequency, machine-level performance, and problem types, the dashboard aids in prioritising maintenance actions and prioritising maintenance resources. These results imply that the dashboard is useful as a practical decision-support tool for daily monitoring and regular maintenance reviews. For automotive manufacturing organisations, especially those early in the digitalisation journey, the dashboard affords a realistic opportunity to improve maintenance planning and performance monitoring and bolster in-house capacity for data-driven decision-making.

This study is limited by its focus on a single automotive manufacturing case and body shop operations, which may restrict the generalisability of the findings to other production areas or industries. In addition, the dashboard relies on manually recorded historical breakdown data, which may be affected by data accuracy, completeness, and consistency issues. The study also does not measure the long-term impact of dashboard usage on maintenance performance or production outcomes. Future research is recommended to evaluate the effectiveness of dashboard implementation over an extended period and across multiple manufacturing sites. Further studies may also explore the integration of dashboard visualisation with automated data collection systems, such as IoT sensors or manufacturing execution systems, to improve data accuracy and enable real-time monitoring. In addition, future research could examine the role of structured training programmes in sustaining dashboard usage and enhancing data-driven maintenance decision-making.

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### **Conflict of interest**

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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