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ENHANCING DATA-DRIVEN SUSTAINABILITY THROUGH DIGITAL QUALITY MANAGEMENT IN AUTOMOTIVE MANUFACTURING

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Abstract
The transformation to sustainable manufacturing requires more than isolated environmental initiatives; it is also necessary to integrate smart, data-driven systems that both improve operational efficiency and minimize waste. With increasing global competition and stricter environmental regulations, industrial companies are increasingly turning to digital transformation as a way to balance quality management with sustainability goals. This study examines how the digitization of quality management processes—through the deployment of modern tools such as CAQ (Computer-Aided Quality) systems, digital platforms can directly lead to environmental and operational sustainability in the automotive industry. The research is based on data collected at an automotive component manufacturing company that transitioned from a paper-based documentation system to a fully digital quality management workflow. The analysis compares process performance indicators before and after digitization, focusing on error rate development and response speed to problems. The results show consistent improvement in all areas monitored. Most notably, the average release time of the production decreased from 1:23:44 in the paper-based system to 00:46:01 in the digital system, representing a 45% reduction. Digital tools not only speed up problem identification but also enable more detailed traceability of production across the entire value chain. Furthermore, the number of administrative steps in the release process was reduced from 14 to 11, simplifying the workflow and minimizing unnecessary handling. In addition to operational benefits, the transition to a paperless and fully traceable environment has also brought clear environmental advantages. The reduction of waste caused by errors, the optimization of raw material usage, and the reduced energy intensity of repair processes have supported the fulfilment of the company's environmental commitments. In addition, the availability of real-time data has enabled the development of predictive and preventive strategies, gradually reducing the environmental footprint of production. The article presents a reference module that links digital quality management tools with sustainability indicators and shows how continuous data collection, advanced analytics, and feedback can serve as inputs for continuous process optimization. The findings underscore the strategic role of digitalization in achieving operational excellence and fulfilling business goals. The study concludes with practical recommendations for organizations that want to integrate traceability metrics into their quality management systems and ensure long-term competitiveness in the face of growing pressure for efficient and environmentally friendly management.
Keywords: digital quality management, CAQ systems, sustainability, Industry 4.0.
JEL classification: M11, O33, Q55

Introduction

In this digital transformation era, there appears to be a trend favouring the adoption of new technologies and the refinement of operational procedures. However, one must realize that the effectiveness of any digital transformation initiative is mostly determined by supporting the human side-the personnel working within these digital settings. Therefore, manufacturers must pay close attention to addressing human factors in digital transformation, so the transition runs smoothly and efficiently (Abdallag et al., 2021). Digitalization has introduced a new phase of modern challenges across multiple industries. The creation of smart factories is highly influencing the lifestyles of workers in manufacturing sectors. Many companies are embracing digitalization with the expectation that it will bring a paper-independent ecosystem and all processes will become completely digital (Pandey et al., 2023). Manual quality data control performed by quality controllers and operators is becoming increasingly complex, which greatly complicates the requirements of modernised production. The use of computer-aided quality management systems currently plays a significant role in the development of final quality in various manufacturing organisations with the aim of improving overall efficiency and standardising control. Digitalization leads not only to innovation of the products themselves, but also to the innovation of individual production technologies, the development of the manufacturing industry in the integration of digitalization and the improvement of the level of product design, processing and management (Zhou, 2013). However, many companies are constantly struggling to define and set effective digital strategies, as a systematic approach plays a significant role in the implementation process (Chirumalla et al., 2025). An additional challenge is the adaptation of the workforce. The transition to a data-driven architecture requires the improvement of employee skills so that they can effectively understand and utilize the knowledge gained from data. Employee aversion to change can slow down the implementation process, highlighting the need for comprehensive training programs and management strategies (Areo, 2023). The digitalization of manufacturing processes has a high impact on the manufacturing sector, an important part of the economy, as the results of such a transformation contribute to sustaining competitiveness and the survival of the organization itself (Sharma, 2024). Also, it's creating significant changes in how manufacturers and providers deliver products and services to the market, which is really supported by government environmental regulations (Albert et al., 2021). It is very likely that many industries, including the automotive industry, will be forced to abandon outdated procedures and gradually begin to automate their processes in order to reduce wasted working time and improve data quality (McKnight 2024 et al., 2024). In the constant competitive struggle, only those companies that can analyse their business operations based on an increasing amount of data and predict optimal process conditions based on this obtained data can succeed in this kind of environment (Krumeich et al., 2014).

Based on these trends, this paper focuses on the transformation from traditional quality management practices to a fully digitized system within the automotive industry. The traditional production release process, consisting of manual form filling, signing and archiving, has often proven to be time-consuming, error-prone and highly inefficient in meeting the requirements of modernized production. Digital solutions based on CAQ platforms and mobile devices enable real-time data entry, automatic record validation and traceability across the entire production chain. The results presented in this research show how digitization can significantly reduce administrative burdens, shorten response times and increase process reliability. At the same time, the transition to a paperless system contributes to environmental sustainability by reducing paper consumption and waste associated with process errors. The research therefore not only highlights the operational and environmental benefits of digitization in quality management but also emphasizes its role as a strategic tool for ensuring long-term competitiveness in the automotive sector.

Theoretical background

Smart technologies have enabled the rapid development of digital manufacturing along with CAM, CAD and CAPP systems, thereby significantly increasing the performance, functionality and overall level of automation of the manufacturing system. These integrations enable the creation of flexible manufacturing cells, digital factories and the production floor, resulting in the evolution to an intelligent manufacturing system that is characterized by information, decision making and execution (Zhou, 2013). Digital transformation is the transition of common manual operations in quality management to digital form. There are many activities that require significant human resources, such as: collecting and analysing data on products, processes and systems, monitoring and controlling processes or making decisions and adapting quality system requirements to changing requirements (Idigova et al., 2022). Computer aided quality (CAQ) management systems facilitate continuous monitoring of production processes, which means real-time quality assessment and if it’s necessary, early intervention in these processes (Salcher et al., 2023). With the constantly growing amount of data generated, there is an increasing demand for efficient and effective forms of data analysis. Having a huge amount of data available is not enough to make data driven decisions, as these data sets can no longer be easily analysed (Chong & Shi, 2015). Using the extensive data analysis capabilities of these systems, manufacturers can obtain useful findings from production data, which facilitates subsequent process optimization (Golubeva & Pogorelova, 2020). The data obtained through various analyses represents an important part of monitoring and continuously improving production processes in order to maintain the competitiveness of the manufacturing organisation. By providing access to relevant information and tools for its simple and quick processing, the CAQ management systems enable a clear analysis of production data and the distribution of statistical results. The user can select the scope of data at any time based on input parameters (e.g. time, production line type, etc.) and therefore obtain relevant information for a specific product or production area (Wiecha & Ćwikła, 2019). In developing the concept of FOF (Factories of the Future), it is necessary to identify potential application principles, technologies and tools in the process of creating and implementing Industry 4.0 approaches (Rakyta et al., 2019). The Industry 4.0 concept refers to new production models incorporating new technologies, production factors and workforce organization (Tambare et al., 2021). Combining quality management with the concept of Industry 4.0 creates the Quality 4.0 model, which is based on the use of traditional quality management methods to facilitate them and thus improve overall performance, efficiency and bring new innovations to traditional approaches (Sony et al., 2020). The combination of lean management and Industry 4.0 leads to the creation of a manufacturing environment in which data can be transmitted in real time (Schäfer et al. 2018). It should be noted that the quality management system in digital production includes intellectual methods that can only be applied if the company is equipped with modern digital technologies (Chesalin et al., 2020). This model uses technologies such as CPS (Cyber-physical systems), Cloud computing and IoT (Internet of Things) to ensure that quality requirements are met by collecting and analysing key components (Sony et al., 2020). The first step is the need to link and collect data from manual paper-based inspections to an automated data collection system that improves data quality and reduces the amount and time required for these processes. IoT manufacturing monitoring adds to the variety of data and parameters that can be tracked. The data collected and aggregated in real-time creates a comprehensive picture of the system being monitored, which is used to create a comprehensive picture of the current status and faster process management (Rakyta et al., 2019). Quality 4.0 places great value on real-time data analysis using machine learning to minimize process variability, find and stop problems and improve overall manufacturing processes. By implementing this model, a manufacturing organization can improve operational efficiency, final product quality and overall customer satisfaction (Tague, 2023). Despite these advantages, the successful implementation rate of Quality 4.0 remains quite low, with empirical studies estimating the successful implementation rate at between 13% and 20% (Escobar et al., 2023). The challenges of data security and workforce adaptation arise in such a system, but the benefits of improved quality control, predictive maintenance and optimized supply chains underscore its strategic importance (Asimiyu, 2024). The complexity of approaches to basic control is reflected in the metrics and performance standards used in modern control systems.

Until now, these metrics have only included traditional quality indicators, but now they also include the effectiveness of the system's learning, the accuracy of its predictions and its ability to adapt (Jain, 2024). Fact-based decision making represents a significant change in automotive manufacturing and opens opportunities for improvement in efficiency, innovation and sustainability (Asimiyu, 2024). The study results from Eversberg and Lambrecht (2023) have demonstrated that the use of digital assistance systems in the manual repair process represents a high potential for reducing costs, errors and mental workload. The proposed digital assistance system uses digital work instructions that are displayed in an augmented reality environment. By observing the set parameters in terms of task completion time, workload and usability of the assistive system, it is shown that manual repairs can be completed 21% faster with 26% less perceived workload using the proposed system. The digital quality management system has contributed significantly to the reduction of internal PPMs and has helped to reduce the number of PPMs from 11 800 to around 6 800. This means that the number of PPMs in the quality area has been reduced by around 60% thanks to digital support (Varela, 2025).

Research methods

The aim of this research was to compare the performance parameters of the traditional paper-based system with the new optimized digital system. These parameters mainly include their efficiency, reliability and contribution to sustainability. The research was carried out in a manufacturing company operating in the automotive industry, focusing on the process of releasing the production. Before the optimization, this process was managed using only paper documentation. Operators were manually filling out, signing and archiving all control forms. This kind of system presented a high risk of large numbers of administrative errors and time-consuming activities. In order to increase efficiency and reduce the number of errors, a digital system based on the CAQ platform and mobile devices (tablets) was implemented and optimized for the process. Process data were collected in two phases. The first phase represented reference measurements using the paper-based system. The second phase represented measurements after the implementation and optimization of the digital system. Each phase lasted for a certain period, because it was necessary to cover variability and ensure the statistical reliability of the collected data. Ten measurements were carried out for each system. Individual measurements were performed repeatedly for different operators and shifts. The start of the measurement was defined as the start of the inspection of the first piece, while the end was defined as approval (signature or confirmation in the digital system).The data were then processed and evaluated. For statistical analysis, all data were first verified for normality of distribution using the Ryan–Joiner test. Since the data from the paper-based system did not necessarily show a normal distribution, the non-parametric Mann–Whitney U test, which is suitable for small samples and abnormal data distribution, was used to compare the two systems. A significance level of 95% was used. The descriptive statistics – means, medians, and standard deviations – were also calculated. Data processing and visualization were performed using Minitab 22 Statistical Software and Microsoft Excel. To supplement the quantitative measurements, a structured questionnaire was distributed among the persons involved in the release process. These individuals include respondents from three different levels. A total of three production supervisors, three quality engineers and eight GAP leaders participated in the survey. The questionnaire contained closed questions (Likert scale and multiple choice) as well as open questions. Data from the questionnaire were processed in Microsoft Forms.

<u>The main areas monitored were:</u>

1. ease of use of the paper and digital systems,
2. perceived reliability and reduction of errors,
3. speed and efficiency compared to the paper-based process,
4. reduction of administrative burden,
5. overall satisfaction and suggestions for improvement.

Results

Paper-based production release system

Before the implementation of the digital production release system, the process in the monitored organization was carried out exclusively through paper documentation. This system was based on paper control sheets, in which it was necessary to manually enter data from the release process. Before each release, the first pieces of a given production batch must be manufactured while checking the individual parameters listed in the control sheet and at the same time, each first piece must be physically measured in accordance with the measurement requirements. After these documents were completed and signed by several responsible people, the document was stored in a designated place at the workplace, which allowed production to continue. This procedure was time-consuming, prone to errors in the form of missing or illegible data and limited the rapid availability of data for operational decisions. In addition, the long-term archiving of paper documentation required considerable space and material costs.

The flowchart of the paper-based production release process (Fig. 1) clearly shows the high amount of manual, administrative and manipulation activities, which significantly extend the time needed for production release and increase the risk of formal errors. Each step of the process requires the operator to manually fill out multiple paper documents, physically submit them for review, and wait for signatures or approvals from responsible persons. This not only causes delays, but also frequent interruptions in the workflow. In addition, the handling and archiving of paper forms represents an additional burden, as documents must be physically stored and searched for.

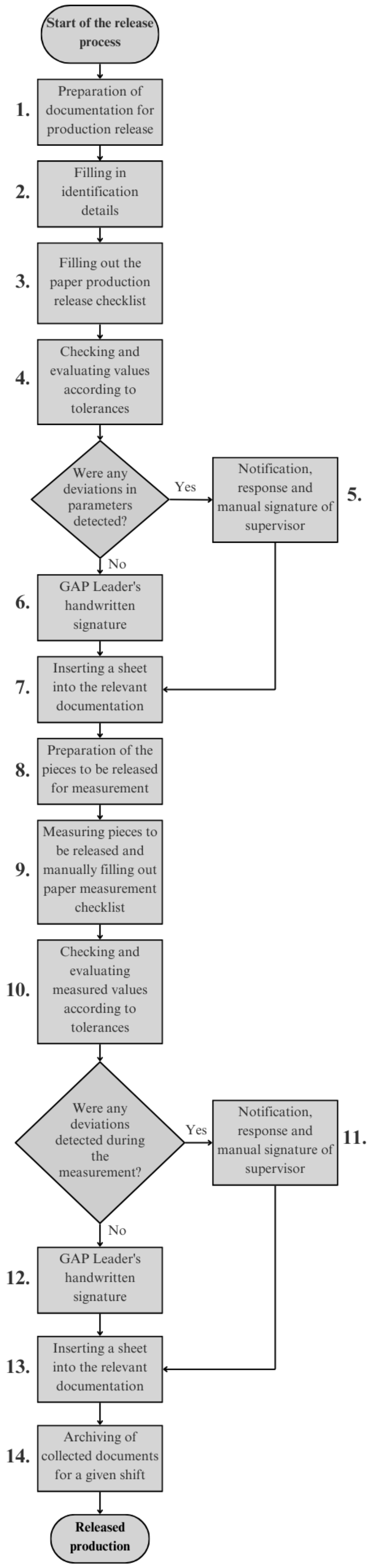

Fig. 1. Flowchart of the paper-based production release process

Source: compiled by the authors

According to the Pareto principle (80/20), we can conclude that most problems associated with paper documentation are caused by one type of error (missing data). This points to the greatest potential for improvement in digitization, as electronic forms use a system of mandatory fields and ongoing automatic checks, which leads to validation and prevents missing or incomplete data. By reducing the presence of this single error, the quality and reliability of documentation can be dramatically improved.

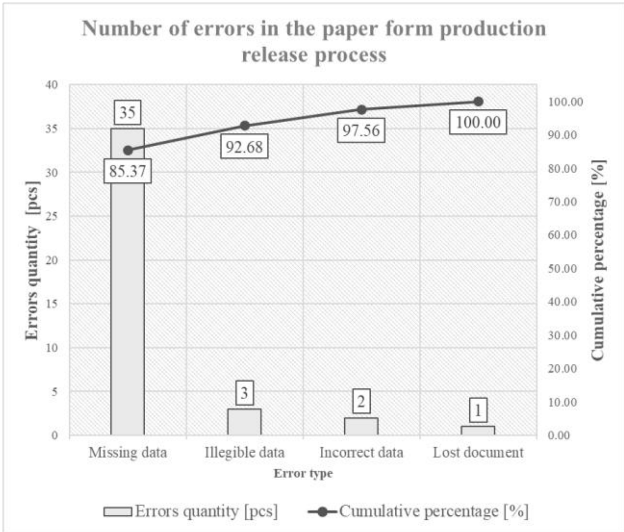

Fig. 2. Number of errors in the paper-based production release process expressed in using Pareto analysis

Source: compiled by the authors

From Table 1, we can see the results of measuring the times of individual steps in the production release process of a paper-based system. Each step was measured ten times. All measurements were taken during different shifts and by different operators to capture the variability of the process. The table shows the measured values in minutes and seconds, their sums and their average values. The total production release time was ranged from 4653 s to 5187 s, with an average value of 5024 s (1 hour 23 minutes and 44 seconds). The paper-based system is time-consuming and consists of several administrative steps that prolong the release time.

Table 1. Time required for individual steps in production releasing using the paper-based system

Step number	Measurement number										$\bar{x}$
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
1.	0:04:24	0:04:40	0:04:32	0:05:02	0:04:41	0:05:20	0:04:48	0:06:01	0:05:15	0:04:42	**0:04:57**
2.	0:00:17	0:00:19	0:00:16	0:00:17	0:00:18	0:00:16	0:00:15	0:00:16	0:00:17	0:00:16	**0:00:17**
3.	0:17:12	0:16:25	0:17:06	0:16:42	0:17:04	0:17:32	0:16:36	0:17:29	0:17:13	0:17:33	**0:17:05**
4.	0:02:26	0:01:36	0:01:55	0:01:49	0:02:11	0:02:21	0:02:34	0:02:46	0:00:00	0:02:25	**0:02:00**
5.	0:00:40	0:00:00	0:00:00	0:00:00	0:00:00	0:00:42	0:00:00	0:00:00	0:00:23	0:00:00	**0:00:11**
6.	0:00:11	0:00:15	0:00:14	0:00:11	0:00:13	0:00:15	0:00:15	0:00:13	0:00:14	0:00:15	**0:00:14**
7.	0:01:53	0:02:02	0:01:42	0:02:01	0:01:56	0:01:59	0:01:58	0:02:02	0:02:05	0:02:14	**0:01:59**
8.	0:27:04	0:23:18	0:24:40	0:26:04	0:23:48	0:25:24	0:26:17	0:24:47	0:27:02	0:25:56	**0:25:26**
9.	0:22:20	0:20:28	0:22:48	0:23:48	0:26:05	0:23:42	0:24:17	0:22:51	0:26:14	0:22:46	**0:23:32**
10.	0:01:08	0:02:36	0:02:48	0:03:16	0:02:28	0:02:00	0:01:45	0:02:10	0:01:39	0:01:55	**0:02:11**
11.	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	**0:00:00**
12.	0:00:12	0:00:11	0:00:12	0:00:13	0:00:11	0:00:10	0:00:12	0:00:10	0:00:09	0:00:11	**0:00:11**
13.	0:00:35	0:00:41	0:00:37	0:00:49	0:00:50	0:00:44	0:00:51	0:00:37	0:00:41	0:00:39	**0:00:42**
14.	0:05:20	0:05:02	0:05:31	0:04:49	0:04:59	0:05:01	0:04:38	0:04:51	0:05:15	0:04:31	**0:05:00**
Σ	**1:23:42**	**1:17:33**	**1:22:21**	**1:25:01**	**1:24:44**	**1:25:26**	**1:24:26**	**1:24:13**	**1:26:27**	**1:23:23**	**1:23:44**
[s]	5022	4653	4941	5101	5084	5126	5066	5053	5187	5003	5024

Source: compiled by the authors

A significant amount of time was spent on preparing, evaluating, checking and archiving documentation, which indicates that the administrative part of the process is the most significant factor prolonging the release process. These results provide a baseline for comparison with the digital system, where a significant reduction in administrative time and overall process duration is expected. Before comparing these two systems, it was necessary to verify the statistical assumptions for the use of appropriate tests. Many parametric tests, including, for example, the two-sample t-test, assume that the data are normally distributed. If this assumption is not met, the test results may not be reliable. In these cases, it is preferable to use non-parametric alternatives, such as the Mann–Whitney U test. For these reasons, we performed a normality test for the measured release times of the first piece in the paper system. The result is shown in the probability graph (Fig. 3).

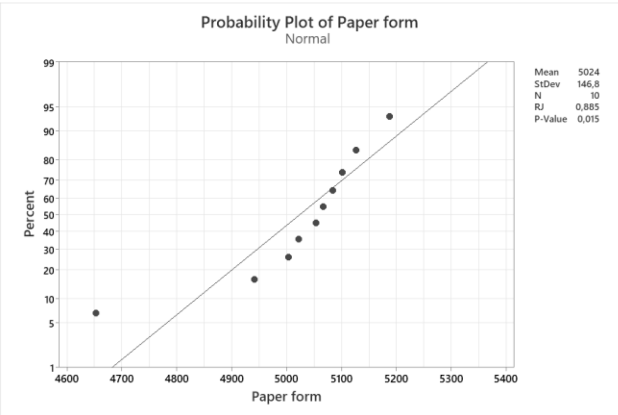

Fig. 3. Probability plot of paper-based system data

Source: compiled by the authors

Based on the plot, we can conclude that the individual points deviate significantly from the ideal straight line, with the resulting p-value of the test ($p = 0.015$) being less than 0.05. This means that the data are statistically significantly different from the normal distribution. In practice, this points to the variability and unpredictability of the paper-based system. Such a process is not stable and is sensitive to various influences. The result further suggests that when comparing paper and digital forms, the use of non-parametric methods of statistical evaluation should be considered.

Digital production release system

The implemented digital system was realized using CAQ platform, into which the original paper-based production release system was transferred. The system works based on electronic checklists, which are available directly on tablets located in the production area. The operators gradually fill in the individual items and without completing them, it is not possible to proceed to the next step or complete the process. This approach acts as an "error-proof" mechanism that ensures data completeness and eliminates the risk of errors that are typical for paper forms (Fig. 6). In terms of process management quality, this is a fundamental change, as the paper-based system relied purely on the operator's reliability, while the digital system includes a control mechanism that significantly increases the consistency and reliability of records.

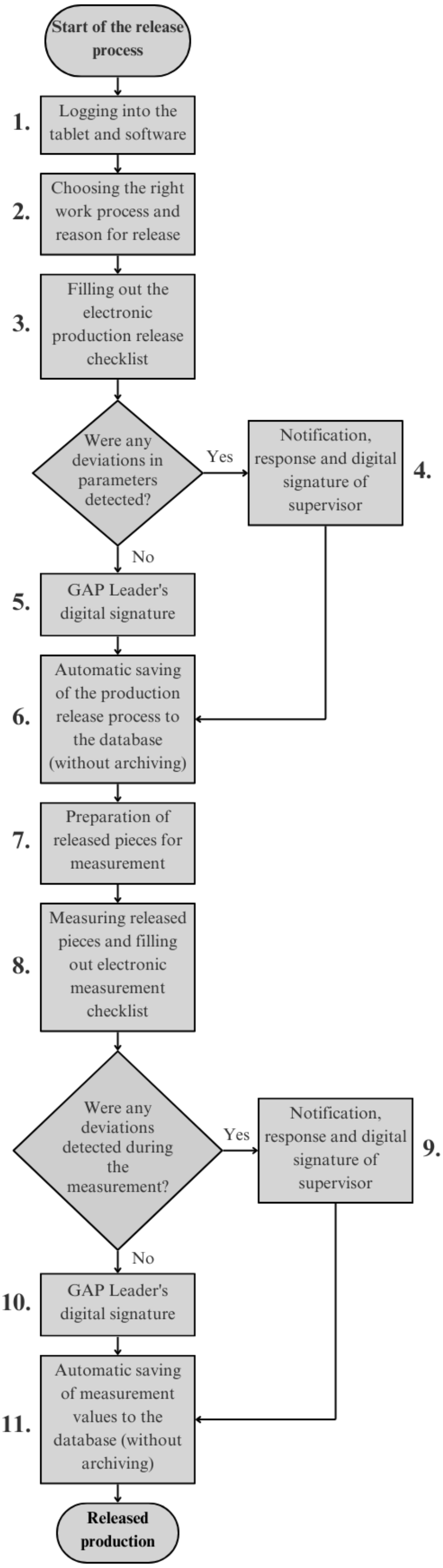

Fig. 4. Flowchart of the digital production release process
Source: compiled by the authors

The digitized process (Fig. 4) is significantly more linear and simpler than the paper-based one. Most handling and administrative tasks are eliminated, which has led to a reduction in response times.

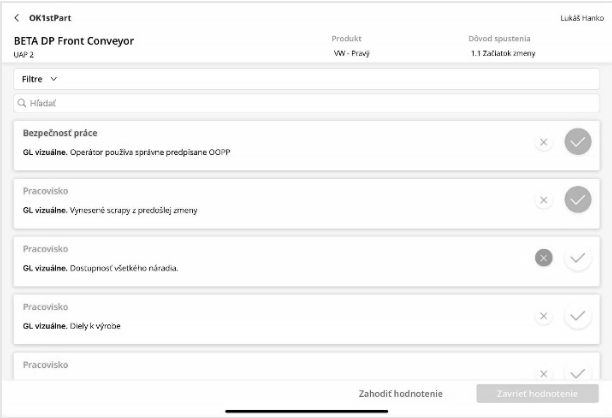

Fig. 5. Digital checklist for production releasing

Source: compiled by the authors

From Table 2, we can see the results of measuring the times of individual steps in the production release process after the implementation and optimization of the digital system in the CAQ platform environment and the electronic checklist system (Fig. 5). As in the paper version, each step was measured ten times during different shifts and by different operators. The results clearly show that digitization significantly reduced the overall process time. The total release time was in the range of 2677 s to 2866 s, with an average value of only 2761 s (46 minutes and 1 second). Compared to the paper-based system, this represents a reduction in process time of approximately 45%. The results confirm that digitization not only improves the efficiency of the release process but also increases its reliability and quality by eliminating the most common sources of errors identified in the paper-based system (Fig. 2). A comparison of process maps confirms the measurement results, as the reduction in the number of steps in the digital system is directly related to the reduction in release time and the elimination of the most common errors that occurred in the paper-based system.

Table 2. Time required for individual steps in production releasing using the digital system

Step number	Measurement number										$\bar{x}$
	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	
1.	0:01:30	0:01:39	0:01:37	0:01:37	0:01:35	0:01:38	0:01:34	0:01:31	0:01:38	0:01:33	**0:01:35**
2.	0:00:54	0:01:17	0:01:21	0:01:13	0:01:16	0:01:02	0:01:13	0:01:21	0:01:25	0:01:23	**0:01:15**
3.	0:07:17	0:06:49	0:08:02	0:07:37	0:08:14	0:08:03	0:07:58	0:08:09	0:07:34	0:07:52	**0:07:45**
4.	0:00:46	0:00:35	0:00:56	0:01:02	0:00:50	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	**0:00:25**
5.	0:00:16	0:00:19	0:00:19	0:00:16	0:00:16	0:00:16	0:00:17	0:00:17	0:00:17	0:00:17	**0:00:17**
6.	0:00:10	0:00:12	0:00:11	0:00:12	0:00:12	0:00:10	0:00:11	0:00:11	0:00:10	0:00:13	**0:00:11**
7.	0:16:40	0:16:20	0:16:43	0:17:35	0:17:20	0:16:20	0:16:49	0:17:01	0:15:59	0:16:31	**0:16:44**
8.	0:18:20	0:18:48	0:17:23	0:17:20	0:17:40	0:17:01	0:17:39	0:18:21	0:16:20	0:16:31	**0:17:32**
9.	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:15	0:00:00	0:00:00	0:00:00	**0:00:02**
10.	0:00:04	0:00:06	0:00:04	0:00:05	0:00:07	0:00:05	0:00:06	0:00:05	0:00:05	0:00:06	**0:00:05**
11.	0:00:04	0:00:10	0:00:13	0:00:11	0:00:10	0:00:11	0:00:06	0:00:11	0:00:10	0:00:11	**0:00:10**
Σ	**0:46:01**	**0:46:15**	**0:46:49**	**0:47:08**	**0:47:40**	**0:44:46**	**0:46:08**	**0:47:07**	**0:43:38**	**0:44:37**	**0:46:01**
[s]	2761	2775	2809	2828	2860	2686	2768	2827	2618	2677	2761

Source: compiled by the authors

A probability plot (Fig. 6) verifies the normality of the distribution of measured release times for the first piece after implementation of the digital system. Ten measurements were performed again. The data obtained had an average value of 2761 seconds with a standard deviation of 77.69 seconds. The value $p > 0.100$ indicates that the hypothesis of normality cannot be denied, which means that the measured data follow a normal distribution. The plot also shows that the individual points are close to the reference line. This distribution confirms good compliance with normal distribution.

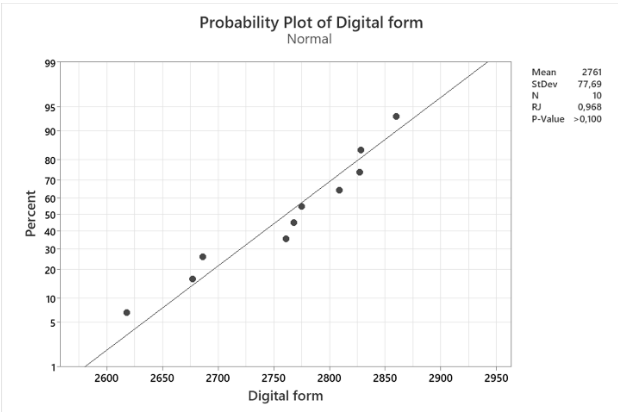

Fig. 6. Probability plot digital system data

Source: compiled by the authors

Comparing it to the original system, which showed higher variability, the results of the new system are way more stable and less scattered. The interpretation of these results directly confirms that the implementation of the digital system has not only contributed to a reduction in production release time but also increased the consistency and reliability of the entire process.

WORKSHEET 1

Mann-Whitney: Paper form; Digital form

Method

η_1: median of Paper form
η_2: median of Digital form
Difference: $\eta_1 - \eta_2$

Descriptive Statistics

Sample	N	Median
Paper form	10	5059,5
Digital form	10	2771,5

Estimation for Difference

Difference	CI for Difference	Achieved Confidence
2281,5	(2194; 2367)	95,48%

Test

Null hypothesis	H_0: $\eta_1 - \eta_2 = 0$
Alternative hypothesis	H_1: $\eta_1 - \eta_2 \neq 0$

W-Value	P-Value
155,00	0,00018

Fig. 7. Statistical evaluation of both systems using the Mann-Whitney test

Source: compiled by the authors

We also used Mann–Whitney test (Fig. 7) to verify the differences between the paper and digital systems for releasing the first piece of production, as the paper form data did not meet the assumption of normality. The test results confirmed a statistically significant difference between the systems. The median time for the paper form was 5059.5 s, while for the digital form it was only 2771.5 s. The difference between the two systems was 2281.5 s (95% CI: 2194–2367). The p-value (0.00018) is significantly lower than the significance level $\alpha = 0.05$, which means that the null hypothesis (equal distribution of times) was rejected.

These results were supplemented by a graphical representation using an interval plot (Fig. 8). This representation visually compares the distribution of times in individual systems and clearly shows that the digital system has a lower median, a narrower distribution of values and lower variability compared to the paper system.

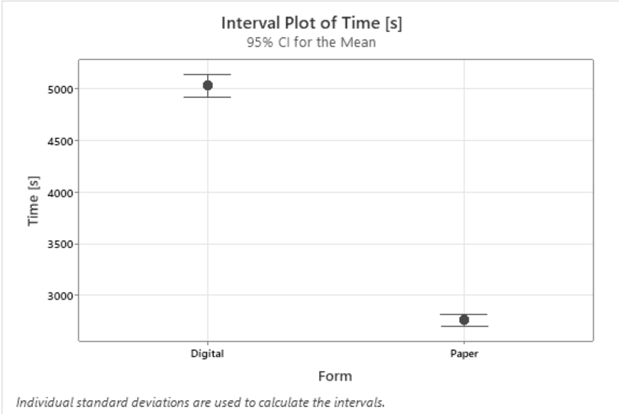

Fig. 8. Interval plot of mean production release time (Paper vs. Digital System)

Source: compiled by the authors

The digital production release system statistically significantly reduces the time required to release the first piece and at the same time provides a more stable and consistent process.

Perception and acceptance of digitization from the perspective of employees

In order to assess not only the quantitative results of the measurements performed, but also the perception of changes and the degree of acceptance of the new system by employees, an anonymous questionnaire survey was carried out among the various job positions involved in the production release process. The questionnaire was structured on a rating scale from 1 (low benefit) to 4 (high benefit) and focused on five main areas: simplicity of use and speed of work compared to paper forms, reliability and accuracy of records, accessibility and searchability of data, reduction of administrative overload and overall satisfaction with the system.

Readability of paper vs. digital systems

Most respondents considered paper forms to be *relatively simple* but also reported *frequent or occasional problems* (e.g. lost papers and illegible data). The digital system was rated significantly more positively, most often as *very simple*, which confirms the reduction in cognitive and administrative burden when releasing production.

Speed and efficiency

The responses showed that the time required to release production is *significantly shorter* or *slightly shorter* with the digital system. This result is consistent with the process data, which showed a real reduction in the time required to release the first piece.

Reliability and number of errors

Most respondents rated the digital system as *very reliable* or *rather reliable*. In terms of errors, the vast majority said that the number of formal errors had *decreased significantly*.

User comfort and overview

When asked whether the digital system simplifies their work, most of the respondents answered, "*I completely agree*." Most employees also confirmed that digitization has given them a *better overview of the process* and records, although there were a few individuals who were more *sceptical*.

Administrative burden

Most responses indicate that the digital system has *significantly reduced* the need for paperwork and archiving.

Open responses

The most frequently mentioned advantages included: data clarity, easier archiving and environmental benefits (paper savings). The problems mentioned included: occasional internet outages, system update and application crashes. Suggestions for improvement: provide more tablets in production, speed up the login process.

Based on the results obtained from the questionnaire, it can be concluded that the feedback from respondents highly reflects their satisfaction with the transition to the digital system. This is also a valuable source of information for further improvement and optimization of this system. The organisation has stated that the comments and suggestions will be considered in the upcoming optimization of processes, with the aim of further simplifying the use of the system, increasing its efficiency and ensuring the highest possible level of user satisfaction.

Conclusions

The results of the study clearly confirm the benefits of digitizing production processes. A comparison of paper and digital systems showed that the implementation of digital tools significantly contributed to reducing the time needed to release production, with the difference being statistically significant. In addition to reducing time, there was also a confirmed reduction in the number of formal errors in documentation and an increase in the consistency of records. The results achieved are also linked to the principles of sustainability, as the digitization of processes leads to the almost complete elimination of paper documentation, thereby directly reducing paper consumption and the associated environmental impact (e.g. printing, archiving, waste, etc.). Faster and more accurate production release reduces the risk of non-compliant products and the associated material waste or additional energy consumption during repairs and downtime. From an organisation's perspective, the transformation to a digital system not only means increased productivity and simplified work for operators, but also a shift towards intelligent and data-driven manufacturing. The results directly lead to recommendations that organisations in the automotive industry, as well as in other manufacturing sectors, should gradually convert their traditional systems to digital solutions such as mobile applications, tablets and CAQ systems. We can conclude that the digitization of processes not only has economic and operational benefits, but also a significant impact on the environmental sustainability of production through waste reduction, resource consumption and production process optimization.

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References

Abdallah, Y. O., Shehab, E., & Al-Ashaab, A. (2021). Digital transformation challenges in the manufacturing industry. *Advances in transdisciplinary engineering*, *15*, 9-14. https://doi.org/10.3233/atde210004

Albert, C., Rubio, F., & Valero, F. (2020). Impact of digital transformation on the automotive industry. *Technological Forecasting and Social Change*, *162*, 120343. https://doi.org/10.1016/j.techfore.2020.120343

Areo, G. (2023). *Data-Driven Decision-Making in Automotive Manufacturing*. Retrieved from: https://www.researchgate.net/publication/387868389_Data-Driven_Decision-Making_in_Automotive_Manufacturing

Asimiyu, Z. (2024). *Data-Driven Decision-Making in Automotive Manufacturing*. Retrieved from: https://www.researchgate.net/publication/387668758_Data-Driven_Decision-Making_in_Automotive_Manufacturing

Chesalin, A. N., Grodzenskiy, S. Y., Nilov, M. Y., & Pham, V. T. (2020). Intelligent quality management tools for digital production and knowledge management system for their application. *IOP Conference Series Materials Science and Engineering*, *862*(4), 042032. https://doi.org/10.1088/1757-899x/862/4/042032

Chirumalla, K., Oghazi, P., Nnewuku, R. E., Tuncay, H., & Yahyapour, N. (2025). Critical factors affecting digital transformation in manufacturing companies. *International Entrepreneurship and Management Journal*, *21*(1). https://doi.org/10.1007/s11365-024-01056-3

Chong, D., & Shi, H. (2015). Big data analytics: a literature review. *Journal of Management Analytics*, *2*(3), 175–201. https://doi.org/10.1080/23270012.2015.1082449

Escobar, C. A., Macias-Arregoyta, D., & Morales-Menendez, R. (2023). The decay of Six Sigma and the rise of Quality 4.0 in manufacturing innovation. *Quality Engineering*, *36*(2), 316–335. https://doi.org/10.1080/08982112.2023.2206679

Eversberg, L., & Lambrecht, J. (2023). Evaluating digital work instructions with augmented reality versus paper-based documents for manual, object-specific repair tasks in a case study with experienced workers. *The International Journal of Advanced Manufacturing Technology*, *127*(3–4), 1859–1871. https://doi.org/10.1007/s00170-023-11313-4

Golubeva, O., & Pogorelova, A. (2020). Development of a software module for quality control and statistical data processing in production. *E3S Web of Conferences*, *217*, 06008. https://doi.org/10.1051/e3sconf/202021706008

Idigova, L. M., Plis, S. A., & Chaplaev, H. G. (2022). Quality Management Digitalization. *Social and Cultural Transformations in the Context of Modern Globalism (SCTCMG 2022)*. *128*, 296-302. https://doi.org/10.15405/epsbs.2022.11.41

Jain, N. D. (2024). Artificial Intelligence in Quality Control Systems: A Cross-Industry analysis of applications, benefits, and implementation frameworks. *International Journal of Scientific Research in Computer Science Engineering and Information Technology*, *10*(6), 1321–1333. https://doi.org/10.32628/cseit241061162

Krumeich, J., Jacobi, S., Werth, D., & Loos, P. (2014). Big Data Analytics for Predictive Manufacturing Control - A Case Study from Process Industry. *2014 IEEE International Congress on Big Data*, *6275*, 530–537. https://doi.org/10.1109/bigdata.congress.2014.83

McKnight, T., Ward, T., & Jenab, K. (2024). Data-Driven quality improvement for sustainability in automotive packaging. *Applied Sciences*, *14*(13), 5723. https://doi.org/10.3390/app14135723

Pandey, R. D., Sarkar, P., & Singh, S. (2023). Success Factors for the Adoption of Paperless Ecosystem in Manufacturing Firms. *2023 IEEE Technology & Engineering Management Conference - Asia Pacific (TEMSCON-ASPAC)*, 1–7. https://doi.org/10.1109/temscon-aspac59527.2023.10531547

Rakyta, M., Bubenik, P., Binasova, V., Gabajova, G., & Staffenova, K. (2024). The change in maintenance strategy on the efficiency and quality of the production system. *Electronics*, *13*(17), 3449. https://doi.org/10.3390/electronics13173449

Salcher, F., Finck, S., & Hellwig, M. (2023). Automated Process Capability Analysis for Product Quality Improvements. *2023 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, 1–9. https://doi.org/10.1109/ice/itmc58018.2023.10332307

Schafer, F., Zeiselmair, C., Becker, J., & Otten, H. (2018). Synthesizing CRISP-DM and Quality Management: A Data Mining Approach for Production Processes. *2018 IEEE International Conference on Technology Management, Operations and Decisions (ICTMOD)*, 190–195. https://doi.org/10.1109/itmc.2018.8691266

Sharma, A. B. (2024). Exploring Digital Transformation in the manufacturing industry: challenges, strategies, and benefits. *Journal of Enterprise and Business Intelligence*, 203–212. https://doi.org/10.53759/5181/jebi202404021

Sony, M., Antony, J., & Douglas, J. A. (2020). Essential ingredients for the implementation of Quality 4.0. *The TQM Journal*, *32*(4), 779–793. https://doi.org/10.1108/tqm-12-2019-0275

Tague, N.R. (2023). *The Quality Toolbox*. Retrieved from: https://books.google.sk/books?hl=sk&lr=&id=0hLqEAAAQBAJ&oi=fnd&pg=PR1&dq=implementation+of+software+tools+for+quality&ots=ZLOFJ4aPLP&sig=8GgD77rHzrZJ9_PgdT-iM4WxhW8&redir_esc=y#v=onepage&q&f=false

Tambare, P., Meshram, C., Lee, C., Ramteke, R. J., & Imoize, A. L. (2021). Performance Measurement System and Quality Management in Data-Driven Industry 4.0: A review. *Sensors*, *22*(1), 224. https://doi.org/10.3390/s22010224

Varela, L. (2025). *Super users:CIE Galfor & Master Audit*. Retrieved from: https://www.mlean.com/wp-content/uploads/2025/02/CIE_EN_2024.pdf

Wiecha, Ł., & Ćwikła, G. (2019). Statistical process control and CAQ systems as a tools assuring quality in the automotive industry. *Multidisciplinary Aspects of Production Engineering*, *2*(1), 336–344. https://doi.org/10.2478/mape-2019-0033

Zhou, J. (2013). Digitalization and intelligentization of manufacturing industry. *Advances in Manufacturing*, *1*(1), 1–7. https://doi.org/10.1007/s40436-013-0006-5

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