SMART PRODUCTION DOCUMENTATION USING QR CODE TECHNOLOGY

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Abstract
This article focuses on simplifying manufacturing processes, increasing their efficiency and reducing human mistakes. The aim of the research was to identify potential areas for improving the inspection and rework process in the production of automotive door panels and to implement a QR code scanning system in order to automatically enter data into the production documentation. To identify opportunities for improvement within inefficient processes, the study focused on reviewing current manufacturing and documentation procedures. The optimization was performed in a manufacturing organization within the automotive industry, evaluating process performance before and after the implementation of data entry using a QR code system. The analysis showed a significant decrease in human errors, an increase in process stability and a radical reduction in the time spent entering data into production documentation. The achieved results point to the potential benefits of digitalization, as such tools contribute to increasing the overall quality and efficiency of production processes.

Key words: *QR codes, digitalization, production process optimization, process automation, error reduction.*

INTRODUCTION

High product quality and operational efficiency are among the key factors influencing organizations to remain competitive. Traditional methods of management and data collection are increasingly becoming inefficient and prone to human mistakes. Automated digital methods offer an alternative by supporting real-time recording of information, improving traceability and enabling information flow throughout the process of production to be quicker. Integrating digitalization and automation into manufacturing offers significant opportunities to increase production productivity, minimize human mistakes and improve process consistency. A study by *Deloitte (2023)* highlighted the significant benefits of intelligent automation in manufacturing, revealing that adopters have achieved an average increase in productivity of 15-25% and a reduction in human mistakes in production of up to 30%. In the area of quality management, this is an important step towards integrating digital elements into the Total Quality Management (TQM) system, which focuses on continuous process improvement and the use of statistical methods for quality control. Another study by *Mangla et al. (2024)* in the area of data entry using QR code scanning has shown significant results, as the time taken to complete the form has been reduced by approximately 80-85% and overall paper consumption has decreased by 40%. Such results can lead to increased operational efficiency and environmental sustainability. The QR code system represents a high potential in transforming tasks that are in some sense data-intensive, as it leads to productivity gains and cost reductions. The implementation of QR code technology also increases the level of traceability, a factor that is becoming increasingly critical, particularly in the automotive industry (*Kormanec et al., 2011*). However, for these technologies to be truly beneficial, they must be carefully integrated into established production workflows. This study focuses on optimizing the inspection and rework process during the production of automotive door panels by implementing a QR code-based data collection system. The aim of this paper was to evaluate the impact of digital documentation on production efficiency.

MATERIALS AND METHODS

The main objective of this research was to optimize the inspection process within the production line of an external automotive company producing door panels. In a production environment, door panel fillers are manufactured and inspected on multiple lines prior to shipment. At the end of the manufacturing process, the individual components are inspected to determine whether they are in order in terms of requirements or have some damage that can or cannot be repaired. If the component complies with the requirements, it goes to the warehouse where it awaits dispatch. Otherwise, if damage is found on the component, the operators mark it, and it goes to the rework station where it is determined whether the damage is repairable or if the component needs to be scrapped. At the rework station, each part is individually inspected to determine the extent of the damage. If the extent permits, the damage is repaired directly at the station. Repaired components must again pass all checks in the manufacturing process before they can be put into storage with the other components. The entire rework process must be documented to ensure the traceability of the components. The optimization consisted of introducing innovative data entry at the rework station by replacing manual entry with QR code systems. This change was made to increase the efficiency of the process and minimize human errors, which are a very common problem with manual entry. The main tracking parameter in such a case was the recording time before and after the introduction of the optimization.

<u>The materials used for the optimization included:</u>

- **QR code labels** – custom QR codes, which has been generated for specified data used on rework station line during documentation processes.
- **QR code scanners** – handheld barcode scanners (model Zebra DS3678) were used to scan QR codes during the rework inspection and documentation processes.
- **Production software** – to automate data collection, the QR code system was linked with the current rework management software (MS Excell).

Barcode Scanner Zebra DS3678 is a wireless scanner designed for harsh production environments and can be used to capture 1D, 2D and DPM codes. It has a wide application range (from 7.6 cm to 21 m) as it supports intelligent imaging and advanced performance within the scanning range. By integrating such equipment into the manufacturing process, we can ensure high process reliability as it supports data collection to minimize human errors. Its advantages include a high degree of protection against water (IP65/IP67) and high drop resistance up to 2.4 m (*Zebra Technologies, 2025*).

Fig. 1 Scanner Zebra DS3678

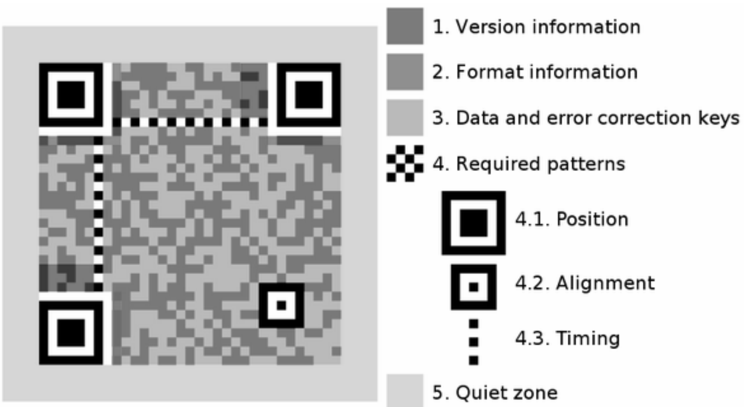

Fig. 2 Scheme of QR code operation *(Porubský, 2011)*

All QR codes are composed of specific "target" elements (parts) which are used for correct aiming and scanning when reading information about the code's format, as well as code versions and the data, which is the most important (*Porubský, 2011*).

To properly evaluate the effectiveness of the impact of QR code implementation, the overall optimization process was divided into two basic phases. The first phase was based on an initial analysis, which involved observing the correction process to quantify and evaluate the initial process of manually recording data on the prepared paper forms. In the second phase, the paper documentation was replaced by an electronic form into which data was entered by scanning QR codes. The staff had defined the individual data and assigned the generated QR codes to them, which they scanned as necessary. Data entry into the electronic forms (MS Excell) was already fully automated and used a script to enter data into individual fields by scanning the necessary QR code. The same analysis was performed again to determine the average time to record data using automatic data entry.

In the case of a comparison of significant time indicators before and after implementation, we can draw conclusions that will certainly confirm that this type of optimization is indeed capable of bringing about a significant acceleration of manual activities and, consequently, the optimization of the entire process. By writing down production data using a QR code, we can achieve faster assignment of certain data to a specific product and avoid manual searches and data entry. All these changes are in line with lean manufacturing principles as they are not only related to improving and simplifying the flow of materials, but also to eliminating waste and increasing the added value for the customer (*Korenko et al., 2019*). Data entry through scanning QR codes, which can carry different types of data, leads to a reduction in human error as they allow users to access data without the need for manual entry (*Nugroho et al., 2024*). Despite all the benefits of data entry via scanning QR codes, we still face challenges, such as ensuring reliable recognition of individual codes under different conditions, as well as security when dealing with sensitive data (*DeSoto & Peskin, 2013*). Generally, in a broader sense, one can argue that such advancements fall in accordance with Industry 4.0 developments driven by digitalization, automation and connecting processes to one another with data. Concepts of digital transformation such as networked devices, intelligent sensors and adaptive control systems are turning into a new standard among modern manufacturing companies (*Cugno et al., 2022*).

RESULTS AND DISCUSSION

First phase of the optimization – before the introduction of QR code scanning

The assigned worker recorded information into a paper sheet, which can be seen in Fig.3. The values that were recorded and which must be entered into the rework documentation were Rework number, Date of rework, Part number, Shift, Component, Defect and Rework/Scrap. This method of input is time-consuming and very often results in errors caused by operator inattention.

REWORK Tally Sheet

Počet Reworkov	Dátum reworku	Číslo dielu	Zmena	Komponent	Defekt	REWORK/ SCRAP
1	7.3.2025 7:43	PDRFR2506602491	A	REPRODUKTOR	CHYBAJUCI DIEL	RWK
2	7.3.2025 7:53	PDRFL2506601792	A	HARDDECO x TOP ROLL	SPARA	SCRAP
3	7.3.2025 7:55	PDRRF2506602554	A	TOP ROLL	VRASKY	SCRAP
4	7.3.2025 7:59	PDPRL2506700831	A	GRABHANDLE x ARMREST	SPARA	RWK
5	7.3.2025 8:04	PDPFR2506602579	A	ARMREST	NECISTOTA	RWK
329	7.3.2025 14:31	VRLU001561	B	INSERT	SPARA	RWK
330	7.3.2025 14:34	SRR0001769	B	REPRODUKTOR	ZLE NAMONTOVANE	RWK
331	7.3.2025 14:40	PDPFR01kX07	B	TOP ROLL	NECISTOTA	RWK
332	7.3.2025 14:45	PDPRR2506501	B	SWITCH	MECHANICKE POSKODENIE	SCRAP
333	7.3.2025 14:48	PDPFL2506500782	B	TOP ROLL	ZLE NAMONTOVANE	RWK

Fig. 3 Sample of paper rework documentation

Tab. 1 Time required to manually enter data into the rework Tally Sheet

Measurement number	Recording time Shift A s	Recording time Shift B s
1.	94.18	79.20
2.	78.24	83.57
3.	86.29	79.48
4.	111.03	86.44
5.	84.47	89.18
Average time	90.84	83.57

Based on the results of the initial analysis, we can observe some variability in the duration of individual entries in the two shifts. Such variability is due to a high probability to the human factor, since the speed of execution of each task varies from worker to worker.

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Second phase of the optimization – after the introduction of QR code scanning
The optimization strategy consisted of generating individual QR codes, assigning them to specific data based on the forms used, and creating a script within MS Excell. Based on this strategy, the entire manual process of registering data within the prepared spreadsheets would be changed to just scanning 4 QR codes followed by auto-filling in the electronic eTally Sheet. The individual scans would include the following data:

- The first scan defines and fills the first three columns of the eTally Sheet – Rework number, Date of rework and Part number.
- The second scan identifies and fills the fourth column of the eTally Sheet – Shift (A or B) on which the rework has been performed.
- The third scan defines and fills the fifth and sixth columns of the eTally Sheet – Component and Defect.
- The fourth scan identifies and fills in the seventh column of the eTally Sheet – REWORK/SCRAP status, which determines whether the piece can be repaired or if it needs to be scrapped.

Version: 02 30.7.2024

REWORK eTally Sheet BETA DP | **SAVE REWORK** | Enter

Rework number	Date of rework	Part number	Shift	Component	Defect	REWORK/SCRAP
1	21.3.2025 8:45	VFLD001824##PDPFL2430200330##10S	A	Insert	Bubble	REWORK
2	21.3.2025 8:47	VRR0001476##PDPRR2430200839##09S	A	Insert	Impurity	REWORK
3	21.3.2025 8:50	VRR1001558##PDPRR2430200659##09S	A	Armrest	Skratch	SCRAP
4	21.3.2025 8:54	SRR0001982##PDPRR2430200881##10S	A	Insert	Extra material	REWORK
5	21.3.2025 8:58	VFLP001881##PDPFL2430201601##10S	A	Grab Handle x Armrest	Bad assembly	REWORK
-	-	-	-	-	-	-
-	-	-	-	-	-	-
122	21.3.2025 14:28	PDPRRXXX#0#3044490KU4	B	Kabel	Bad assembly	REWORK
123	21.3.2025 14:29	VFLD001590##PDPFL2430202523##10S	B	Insert	Extra material	REWORK
124	21.3.2025 14:30	PDPRR2430202228#403042601XXX#3044741XXX#4173048(	B	Reproduktor	Interchange	REWORK
125	21.3.2025 14:31	VFRP001305##PDPFR2430202064##10S	B	Armrest	Wrinkles	SCRAP
126	21.3.2025 14:32	PDPFL2430200954#403643701KU4#2997434XXX#4175587(	B	Top Roll	NOK Punching	SCRAP

Fig. 4 Sample of digital rework documentation

Tab. 2 Time required to enter data into the rework eTally Sheet with the QR codes scanning

Measurement number	Recording time Shift A s	Recording time Shift B s
1.	12.17	10.98
2.	13.04	12.41
3.	16.55	13.08
4.	17.11	11.91
5.	15.43	12.22
Average time	14.86	12.12

To calculate the time savings before and after the implementation of the optimization, we used a simple calculation that can be used to express absolute (equation 1) and relative (equation 2) time savings.

Absolute time saving:

$$Time\ Saving\ (absolute) = t_{before} - t_{after} = 87.21 - 13.49 = 73.72\ s \qquad (1)$$

where t_{before} is data entry time before the optimalization (s) and t_{after} is data entry time after the optimalization (s).

Relative time saving:

$$Time\ Saving\ (\%) = \left(\frac{t_{before} - t_{after}}{t_{before}}\right) * 100 = \left(\frac{87.21 - 13.49}{87.21}\right) * 100 = 84.53\% \quad (2)$$

where t_{before} is data entry time before the optimalization (s) and t_{after} is data entry time after the optimalization (s).

Analysis and comparison of times before and after the introduction of QR code scanning technology showed a visible reduction in time and an increase in process stability. The optimization reduced the time, the total data writing time by 84.53% and the probability of writing errors was reduced to a minimum. The main reason for the time saving was the complete elimination of tedious manual searching and writing of data into printed sheets. The main reason for reducing errors to a minimum was the elimination of the possibility of a bad reading or writing to the wrong field in the sheet.

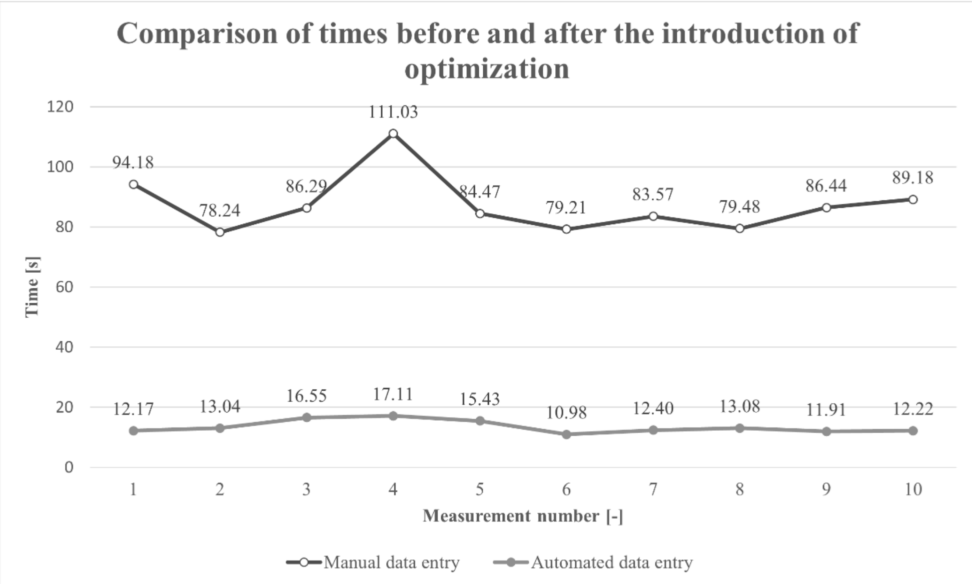

Fig. 5 Comparison of times before and after the introduction of optimization

Based on the comparison of times before and after the introduction of optimization (see Fig.5), we can see that the optimization has led to significant time savings and lower variability within the data entry process. Variations within individual measurements of up to 30 seconds can be observed in manual data logging, mainly due to the difficult and lengthy searches in the sheets. With automatic data entry using QR code scanning, a decrease within the differences to a maximum of 5 seconds can be seen. Such a decrease and consistency contribute to increased productivity in the process, as workers do not have to spend as much time performing administrative activities, but can spend more time on repairing components, leading to an increase in the number of repairs per shift.

Optimization by using automatic data entry within the production line has significantly increased the reliability of the production process, which actually confirms to us the strong potential of using simple digital tools in a manufacturing environment. The results of the study confirm and emphasize the benefits of digital transformation in manufacturing and are consistent with the findings of previous studies. A study by *Sony & Naik (2020)* also showed that the use of simple digital tools such as QR and barcode-based systems leads to significant improvements in traceability and data accuracy in quality management processes. According to *Kamble et al. (2019)*, the implementation of Industry 4.0 technologies supports increased operational efficiency along with fact-based decision-making. In line with *Tortorello & Fettermann (2017)*, the results obtained confirm that digital tools lead to a reduction in process variability by simplifying administrative tasks and increasing overall customer satisfaction. Therefore, the use of QR codes in production documentation can be considered a highly effective and cost-effective step towards continuous improvement in production.

CONCLUSIONS

The results achieved by optimizing the data recording process using QR code scanning have demonstrated a significant impact on production efficiency and reliability and therefore confirm the validity of the changes introduced. The time originally required to document the data of a single component has been reduced by an average of 84.53%. The variability of the time for individual tasks has also been significantly reduced, from differences of up to 30 seconds for manual entry to around 5 seconds when using the QR code scanning system. In addition to the technological benefit itself, we can observe an increase in the quality of the input data, which contributes to improved process monitoring and the identification of potential anomalies. The digitalization of documentation has eliminated human mistakes to a high level. To conclude, the introduction of QR code-based data recording not only streamlined internal processes but also demonstrated the broader potential of simple digitalization measures and digital tools to enhance manufacturing performance and support continuous process improvement initiatives.

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