DIGITALIZATION OF SHOP FLOOR MANAGEMENT AT SELECTED SEGMENT IN THE INDUSTRIAL ENTERPRISE IN THE CONTEXT OF INDUSTRY 4.0

JANA MESAROSOVA[1], KATARINA LESTYANSZKA SKURKOVA[1], ZDENKO VIZVARY[2]

[1]Slovak University of Technology in Bratislava, Slovak Republic

[2]Schaeffler, Skalica, Slovak Republic

DOI: 10.17973/MMSJ.2024_11_2024024

jana.mesarosova@stuba.sk

As businesses gradually transition to the concept of Industry 4.0, they strive to digitize all necessary data. The aim of this article is to demonstrate how the digitalization of shop floor management (dSFM) can enhance the efficiency of production process management, and to propose steps for faster and more effective implementation of dSFM in industrial enterprises. The digitalization of shop floor management increases agility, responsiveness, and overall improves decision-making processes. In the analyzed enterprise, the traditional shop floor management was overly burdensome, accompanied by excessive documentation and inefficient processes. It was necessary to analyze three areas: data collection, information visualization, and the flow of shop floor meetings. Based on this analysis, shortcomings were identified, and measures were proposed to automate routine activities and streamline processes. This case study thus fills a gap in the research by focusing on specific challenges in implementing dSFM in an industrial enterprise.

KEYWORDS

Digital shop floor management, Industry 4.0, Lean management, optimization of process,

1 INTRODUCTION

The advent of Industry 4.0 marks a transformative period in manufacturing, characterized by the integration of advanced digital technologies into traditional industrial processes. At the core of this evolution is the digitalization of shop floor management (SFM), a critical function responsible for overseeing daily production operations [Wester 2022, Zondo 2020]. Historically, production management has relied on manual processes, paper-based systems, and periodic reporting [Gisi 2023, Makysova 2024]. Although functional, this approach frequently resulted in inefficiencies, delays in decision-making, and a lack of transparency regarding the real-time status of production. The limitations of traditional SFM have become increasingly evident with the growing complexity of modern manufacturing and the rising demand for customization and agility in responding to market changes [Clausen 2020].

Traditional SFM faces several challenges, including inadequate real-time data visualization, poor communication between teams and departments, difficulties in managing and analyzing large volumes of data, a shortage of skilled personnel capable of effectively utilizing modern technologies and methodologies, and the absence of agile approaches necessary for rapid adaptation to changes in demand, technologies, or processes [Materna 2019].

Addressing these challenges requires a systematic approach and the digitalization of individual processes [Meissner 2020, Moica 2020, Tauber 2019]. Industry 4.0 introduces a new paradigm in which digital technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), and Big Data Analytics, are integrated into manufacturing processes. This digital transformation of SFM enables manufacturers to achieve unprecedented levels of operational efficiency, product quality, and flexibility [Oborski 2018, Jamwal 2021, Paramawardhani 2020]. A significant advantage of dSFM is the availability of real-time data, which allows qualified personnel to make prompt and accurate decisions when Key Performance Indicators (KPIs) indicate a decline in quality, productivity, or, for instance, a deterioration in safety on the production floor. Digitalized SFM also enhances overall communication, enabling managers to convey identified issues more effectively and systematically to other employees, thereby preventing errors in the decision-making process [Muller 2021].

While the advantages of dSFM are generally acknowledged, fewer than 20% of companies currently utilize digital visual boards [Potters 2018, Clausen 2021]. Despite the numerous benefits, the digitalization of SFM presents several challenges, including high initial investment costs, the need for workforce upskilling, and concerns regarding data security and protection [Clausen 2018, Kandler 2022]. Furthermore, integrating new digital systems with existing legacy systems can be complex and requires careful planning and execution. According to Meissner [Meissner 2018], the primary barriers to implementing dSFM include a lack of expertise among specialists and managers, a phenomenon described as "data blindness"—wherein professionals may struggle to interpret relevant data due to an over-reliance on technological capabilities—and cultural resistance within the organization to new workflows and technologies.

Although the transition from traditional SFM to dSFM represents a resource-intensive and time-intensive process for companies, organizations must recognize that this does not necessarily need to be a painful transition. As Clausen [Clausen 2023] notes, it is neither necessary nor desirable for all SFM activities to be automatically digitalized. For instance, some companies may prefer onsite meetings guided by the popular "power of the pen" approach, in which problem-solving methods are sketched out on traditional visual boards. In contrast, the collection and visualization of data in real time are essential for addressing production issues. Within the Industry 4.0 framework, however, it is imperative for companies to understand the importance and necessity of digitalization and to adapt their established practices accordingly.

Existing scholarly publications do not specifically address the transition from traditional SFM to dSFM within a particular industrial enterprise. Motivated by this gap, the present paper examines the practical challenges an industrial enterprise faces when transitioning to dSFM. A case study is presented that follows the daily activities of managers at three levels of management, identifying the main deficiencies of traditional SFM. The findings corroborate previous studies [Grundnig 2018, Meissner 2020], indicating that managers spend an excessive amount of time preparing for SFM meetings by manually collecting and processing data for traditional visual boards (VB). The paper further details the specific steps taken to digitalize selected processes and evaluates the implemented solutions

through a survey of managers across different management levels. Based on this study, the principal challenges in implementing digitalized SFM in an industrial enterprise are identified, leading to the proposal of six key steps to streamline and simplify the process.

2 BACKGROUND OF RESEARCH

The following section outlines the fundamental concepts related to the primary subject of this paper, which is digital shop floor management. This chapter also includes an analysis of the number of publications on the topics of shop floor management and digital shop floor management in two citation databases, Web of Science (WOS) and SCOPUS, aiming to demonstrate the relevance and timeliness of the topic under investigation.

2.1 *Theoretical background*

Shop floor management is among the core techniques of Lean Management. *Lean Management* is a philosophy and a set of techniques aimed at maximizing customer value while minimizing the seven basic types of waste (Overproduction, Waiting, Transport, Inventory, Motion, Over-processing, Defects) [Klein 2021, Paramawardhani 2020, Dyadyura 2021]. These wastes represent inefficient activities or resources that do not add value to the customer. The objective of Lean Management is to eliminate or minimize these wastes to increase efficiency and productivity. Key Lean Management techniques include Bottleneck Analysis, Takt Time, Cellular Manufacturing, Single Minute Exchange of Die (SMED), Total Productive Maintenance, Visual Management, Work Standardization, 5S, Just-In-Time, Kaizen, and Kanban [Kumar 2022]. Lean Management helps organizations operate more efficiently, respond more flexibly to market needs, and deliver greater value to customers, leading to long-term sustainability and market success [Bertagnolli 2022, Saxby 2020, Lakshmanan 2023].

Shop floor management has been described as a system that provides a bottom-up information flow in production with the use of key performance indicators, action plans and regular short meetings at the shop floor. It involves the coordination and supervision of all activities that occur in the production area, with a focus on improving efficiency, quality, and productivity. Shop Floor Management emphasizes the importance of involving employees in decision-making and problem-solving processes [Wester 2022, Dewald 2021]. Shop floor management encompasses specific activities on the production floor and elsewhere in the factory, with the aim of creating a clear, safe, stable, and actionable workflow [Chen 2022]. It is based on four methodical elements: Visual management; Communication structure; Problem-solving process and Standard-based process observation [Bertagnolli 2022].

Digital shop floor management represents a significant evolution in manufacturing management, utilizing digital technologies to create more efficient, responsive, and adaptable production systems. Digital Shop Floor Management is characterized by several key features that distinguish it from traditional shop floor management. These features leverage advanced digital technologies to enhance the efficiency, visibility, and responsiveness of manufacturing operations. Here are the primary characteristics of dSFM [Clausen 2020, Torres 2020, Clausen 2021]: Real-Time Data Collection and Analysis; Enhanced Visibility and Transparency (real-time overview of KPI); Improved Communication and Collaboration (MES, ERP) [Halevi 2017]; Flexibility and Adaptability to Market Changes; Predictive Maintenance and Reduced Downtime; Real-Time Quality Monitoring and Automated Quality Checks [Liu 2023]; Cost Efficiency and Resource Optimization. These characteristics highlight how dSFM enhances traditional shop floor management by incorporating digital technologies, leading to more efficient, flexible, and transparent manufacturing operations.

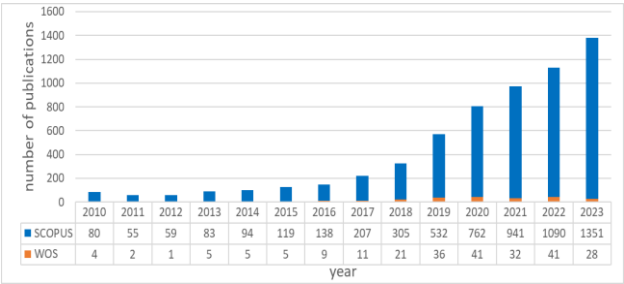
Industry 4.0 often referred to as the Fourth Industrial Revolution, represents a new phase in the industrial sector characterized by the integration of digital technologies into manufacturing processes [Liu 2023, Richnak 2022]. Industry 4.0 revolves around the use of cyber-physical systems (CPS) where physical and digital systems are interconnected. These systems communicate and cooperate with each other and humans in real-time through the Internet of Things (IoT) and cloud computing [Zhang 2021]. A significant feature of Industry 4.0 is the utilization of big data analytics and machine learning to derive insights and optimize production processes. Enhanced automation through smart manufacturing technologies allows for self-monitoring, analysis, and diagnosis without human intervention, leading to higher efficiency and productivity in manufacturing operations. Industry 4.0 supports flexible manufacturing systems that can quickly adapt to changes in production requirements and allow for mass customization of products. Fourth Industrial Revolution involves horizontal and vertical integration of production systems. Horizontal integration connects different production facilities, while vertical integration links various layers of the organization, from the shop floor to management levels, ensuring cohesive operations [Abdelmajied 2022, Lemstra 2023, Elnadi 2024, Kmec 2018].

2.2 *Literature review*

As part of the analysis of the theoretical background, we focused on examining the number of publications on the topics of shop floor management and digital shop floor management in two citation databases, WOS and SCOPUS, from 2010 to 2023.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
SCOPUS	730	721	773	822	863	919	985	1098	1258	1508	1781	1836	1989	2201
WOS	61	71	78	82	73	91	127	133	120	167	146	112	116	83

Figure 1. The topic of shop floor management in world databases WOS and SCOPUS in the years 2010 - 2023



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
SCOPUS	80	55	59	83	94	119	138	207	305	532	762	941	1090	1351
WOS	4	2	1	5	5	5	9	11	21	36	41	32	41	28

Figure 2. The topic of digital shop floor management in world databases WOS and SCOPUS in the years 2010 - 2023

The aim of this analysis was to demonstrate the relevance of the issue at hand. Figure 1 shows a growing trend of academic articles on the topic of shop floor management in the SCOPUS database. In the WOS database, the highest number of publications occurred in 2019, after which a downward trend is visible. With the advent of Industry 4.0, digitalization also

affected shop floor management. This is evident in Figure 2, which shows a significant increase in publications in the SCOPUS database on the topic of digital shop floor management since 2017.

In the second step of the theoretical background analysis, a bibliometric analysis was conducted using the VOSviewer software [Perianes-Rodriguez 2016], which utilizes datasets created from the WOS and SCOPUS citation databases. For this analysis, a dataset was created from the SCOPUS database, focusing on the keyword "shop floor management." A total of 24 962 documents were found. This set was filtered using three filters. Filter 1: Subject area – engineering, business, management and accounting, economics and finance, multidisciplinary. Filter 2: Only articles with open access were selected. Filter 3: Document type – journal articles. Based on these filters, 3 202 documents were created, which were then converted into an MS Excel file and processed in VOSviewer. The created bibliometric network in Figure 3 shows that during the years 2010–2020, the topic of shop floor management appeared in various research areas. While in 2012, the topic was mostly present in publications related to Scheduling and Production Control, by 2020, it had shifted to areas such as Digital Twin, Smart Manufacturing, and Industry 4.0. Based on the theoretical background analysis, it can be concluded that the topic of shop floor management remains relevant, with data collection and information sharing increasingly shifting to digital formats in the context of Industry 4.0.

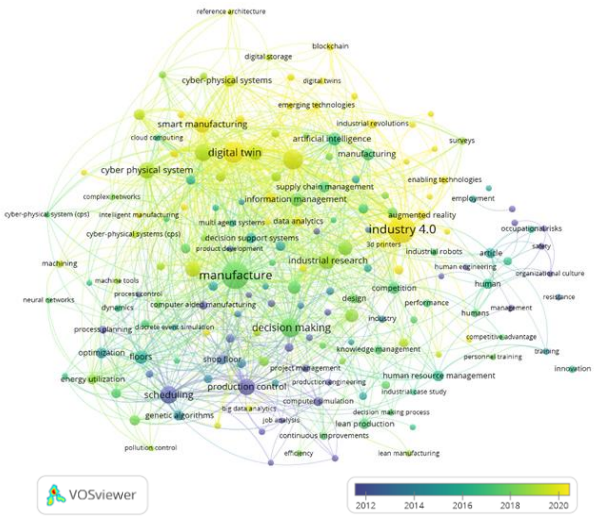


Figure 3. Bibliographic analysis - keyword “shop floor management”

3 METHODOLOGY

This chapter defines the analyzed enterprise and outlines the steps followed in conducting the case study.

3.1 *Research objective*

The main objective of the research was to identify, through a case study, the primary challenges that an industrial enterprise encounters during the implementation of digital shop floor management and, based on the findings, propose steps to facilitate and shorten the implementation process for other industrial enterprises.

3.2 *Description of the industrial enterprise and methodology*

The analysis of shop floor management was conducted in an industrial enterprise on a selected production segment, designated as S3. This segment was created by merging three production segments and includes several manufacturing operations (forming, heat treatment, grinding, turning) as well as the final product assembly. The production segment is managed by a production manager who oversees three team leaders. Each team leader is responsible for a specific production area, which encompasses similar production technologies. Discipline and accuracy of the information provided, which is communicated from the lowest to the highest level, are crucial for the effective implementation of SFM. If the data is inaccurate, it may lead to poor decision-making and inefficient management of the production area. Thus, the analysis examined the course of SFM across three management levels, from the lowest to the highest: 1. the workplace level, 2. the team leader level, and 3. the production manager level.

The methodology for analyzing the established shop floor management and subsequently designing the digitalization of SFM in the selected industrial enterprise followed nine steps. The entire process took one calendar year. The purpose of the analysis was to confirm waste occurrences in traditional SFM and propose measures to help the enterprise successfully optimize and digitalize SFM. As part of the analysis of the current SFM, the authors also used the Danish SFM model [Clausen 2023], based on Lean management principles. The individual steps of the analysis and design development are as follows:

1. Defining the objectives and scope of the analysis - the objective was to identify the main challenges in the digitalization of shop floor management in an industrial enterprise. The scope of the analysis was limited to the S3 production segment.
2. Data collection and analysis - all data and information on SFM visual boards, as well as all visualized KPIs at the three management levels, were subject to analysis.
3. Process analysis - bottlenecks were identified in the processes required to execute SFM. A workday snapshot of managerial staff at the three management levels was performed: workplace level, team leader level, and production manager level. The course of SFM meetings and communication channels between SFM team members were analyzed.
4. Root cause identification - root causes of problems in process bottlenecks were identified using Lean methods (5 Why’s, Ishikawa diagram [Iuga 2017]).
5. Solution development - based on the root causes, measures were proposed for optimizing and digitalizing SFM in the industrial enterprise in the context of Industry 4.0. The design team consisted of experts from among the enterprise's employees (production manager, segment manager, quality manager, team leader, technologists, digitalization specialists, MES expert, SFM multiplier, and IT leader).
6. Implementation of solutions - the proposed optimization and digitalization measures for SFM in the selected S3 segment were gradually implemented.
7. Monitoring and feedback - feedback on optimized and digitalized SFM processes was gathered three months after implementing the proposed measures using a questionnaire (Google Forms). Control snapshots of the workday of managerial staff at the three management levels were also performed.
8. Identification of major issues in dSFM implementation - the identification and description of the main problems in dSFM implementation were based on the results of the survey and control snapshots of managerial staff workdays.
9. Proposal of steps to facilitate and shorten the dSFM implementation process - description of specific six steps focused on key areas that form barriers to dSFM

implementation in the industrial enterprise. The goal of these steps is to ease and shorten the dSFM implementation process in other industrial enterprises.

4 RESULTS AND DISCUSSION

An analysis of the current state of shop floor management was conducted at various management levels in the industrial enterprise, following the procedure outlined in Subchapter 3.2. The analysis of selected employees at different management levels was based on a Workday Snapshot (WS). The research also included an analysis of the course of SFM meetings, communication methods between SFM team members, and an examination of visualization boards and KPIs.

4.1 *Analysis of the established shop floor management in the industrial enterprise*

Figures 4a–c present the results from the workday snapshot of selected employees at the workplace level, team leader level, and production manager level. The snapshot primarily focused on activities related to data collection, data processing, and communication for the preparation of SFM. All these activities are depicted in red in the graphs.

The workday snapshot of a production worker (Figure 4a) shows that the monitored activity "Data collection and documentation creation for SFM" is the second most performed activity. This activity accounts for 15.83% of the total working time of the employee. This is due to the relatively large amount of documentation and the need for its regular updating to prepare for the shop floor meeting.

The workday snapshot was then performed at the next management level, covered by the team leader. The most significant problem identified at the team leader level (Figure 4b) was the time-consuming nature of preparing materials for SFM due to the large number of KPIs. The extensive number of monitored indicators resulted from merging the original three segments into one segment, S3. This task took the team leader 26.04%, which represents a relatively large portion of the work shift (about 2 hours). The excessive number of KPIs affected the efficiency of the SFM, manifesting in the cyclical repetition of some deviations. The analysis also involved the active participation of one of the article's authors in SFM meetings, aimed at analyzing communication among SFM team members. The analysis noted a reduced focus among SFM participants due to the large volume of information during daily meetings. During the team leader's workday snapshot, waste was also identified in the form of repeated trips to the computer for various work reasons.

The production manager's job is based on managing subordinates within the given production segment. The majority of their work involves communication with employees, so it is crucial that communication flows function smoothly without significant barriers. During the COVID-19 pandemic, the company management had to move shop floor meetings to an online format. However, this form of communication brought numerous problems, resulting in inefficient and, in some cases, erroneous production management. The company management wants to be prepared for a similar situation in the future and also wants employees who cannot be physically present on-site to participate in the shop floor meeting.

The production manager is responsible for the collection and recording of data at the third level of management. The data collection begins by recording information from reports into a notebook, while the remaining data is gathered directly during the Daily Walk (DW) with the team leader. The production manager then records and processes this data to ensure the visualization is prepared for the segment manager's daily walk.

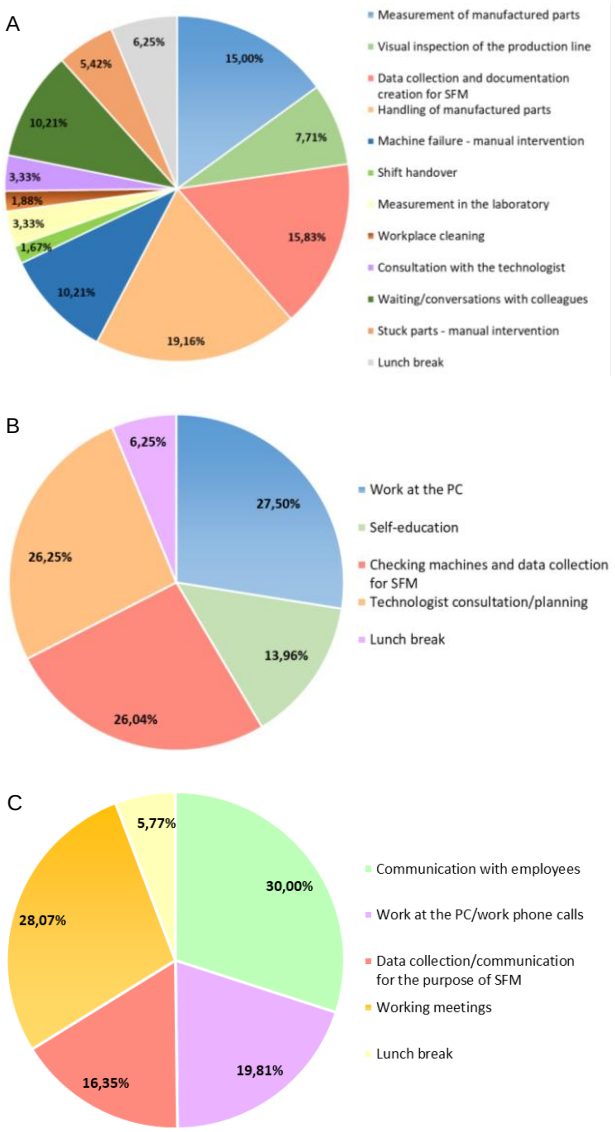


Figure 4. Evaluation of the workday snapshot a) of the production worker at the heat treatment workplace b) of the team leader c) of the production manager [Vizvary 2022]

The analysis of the production manager's workday (Figure 4c) revealed that activities such as data collection and communication for the preparation of SFM take up 16.35% of the total work time. There is also potential for optimizing this activity through automated data collection. The graph in Figure 4c shows that, similar to the team leader, the most time-consuming activity for the production manager is "Communication with employees" (30% of the total work shift). The second-largest portion, accounting for 28.08%, is "Work meetings," such as FMEA meetings or quality-related discussions. The third portion, at 19.81%, is "Work at the PC/work phone calls," which involves reading emails, monitoring data and information, and processing tasks.

Part of the analysis also focused on visual boards and the importance of individual KPIs. Figure 5a-c shows the visual boards from each level of management, on which the documents necessary for the successful conduct of SFM meetings are placed. Figure 5a shows a visual board (a rotating three-stand) on which the documents that are updated at the workplace level by a worker according to well-defined rules are displayed. The team leader's duties also include monitoring the progress of performance on the machines at two-hourly intervals using the form on the three-stand above. In total,

there were 12 documents on the three-stand (Figure 5a), some of which were updated by the worker and some by the team leader. Due to the great number of documents, it is necessary to re-evaluate the importance of these forms and their impact on the management of the production area.

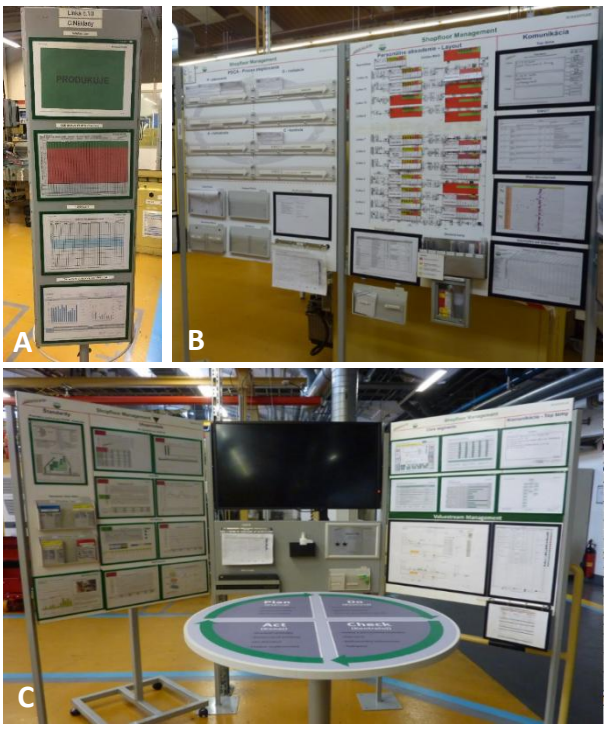


Figure 5. Visualization boards at the level of a) production worker b) team leader c) production/segment manager [Vizvary 2022]

Based on a thorough analysis of the current state of SFM on the S3 segment in an industrial enterprise, the following gaps have been identified:

Poor information management - managing and analysing large amounts of data can be challenging, especially if the data is dispersed or unstructured. In the enterprise analysed, a large amount of data was collected by manual entry, which is inefficient and time-consuming. Difficulties in monitoring and controlling production processes in real time can lead to inefficiencies and errors. The greatest waste associated with data collection and processing was noted at the second level of team leader, where the activity took up to 26.04% of the team leader's time.

Inefficient visualization - processing the collected data into the required visual form is time-consuming for the production worker and team leader. Printing important data and pinning it to SFM visual boards is inefficient and unsustainable.

Inefficient conduct and management of SFM meetings - with a large number of KPIs, SFM meetings were unnecessarily prolonged, causing unfocused SFM team members and subsequent management and decision-making errors. Inconsistent communication between teams and departments can cause misunderstanding of tasks and disrupt workflow.

4.2 *Proposal for optimization and digitalization of shop floor management in the S3 production segment*

Based on the conducted analysis, proposals were developed to optimize and digitalize shop floor management in the context of Industry 4.0 for the selected S3 segment. Due to the different methods of data collection and visualization at individual workplaces, the measures were divided into three parts: 1. the workplace level, 2. the team leader level, 3. the production and segment manager level (the level of the production manager and the segment manager are separate areas in the analyzed company. For the purposes of this work, they are described as one level since they share a workplace for SFM).

1. Proposed measures at the workplace level:

Installation of a Manufacturing Execution System (MES) at individual workplaces in segment S3 - due to the gradual transition of the analyzed company to the Industry 4.0 concept, it was necessary to automate data and information collection in real-time from all machines at the workplace.

Elimination of paper forms at the SFM workplace - based on the visualization capabilities of SFM directly in the MES, it was possible to reduce the number of KPI forms from 12 to 3, representing a 75% reduction.

Training of staff to work with the MES information system - as this is a relatively large change in the way data and information is recorded, it was necessary to organise training for the production staff on the new MES equipment with data transfer to SAP.

2. Proposed measures at the team leader level:

Setting KPIs for individual segment work teams S3 - after performing an analysis of critical machines based on results from Overall Equipment Effectiveness (OEE), percentage of defective parts and other indicators, KPIs were selected for tracking on a daily basis.

Utilization of data from the MES at workplaces - the time-consuming acquisition and processing of team leader data was solved by using FactoryFramework. The dashboard with online tracking of machines and equipment is a great asset, which allowed to cancel two-hourly checks of the entire production.

Conversion of visual board to a digital board with a touch screen monitor - one of the measures is the digitisation of documents with the complete elimination of paper. For the needs of the company, the PADS application was chosen, which allows the display of PDF files on a monitor (Fig. 6a).

Creation of an online communication platform - two years ago, the company's management had to move its operations online due to the Covid-19 pandemic. The company wants to prepare for a similar situation in the future, where meetings are conducted online. For this purpose, the company established the Microsoft Teams platform, allowing all SFM participants to meet at the same time, improving the resolution of deviations related to the absence of individual experts at meetings.

Retraining of team leaders on the measures in place - for the effective use of all the measures put in place it was necessary to train team leaders on the applications and tools used for digitalization and simplification of work.

Tablet workstation equipment - when capturing the working day at the team leader level, there was also waste associated with the team leader repeatedly moving to the computer for various work-related reasons. This shortcoming was solved by purchasing an industrial tablet for the team leader, who thus receives information and sends requests directly from the production site where he/she is currently located.

3. Proposed measures at the production manager level:

Setting KPIs - to achieve effective management, it was necessary to divide the KPIs into three blocks, according to the three areas of production. This division allowed, in the event of a deviation, a clear identification of the production area in which the targets are not being met.

Assigning responsibility for updating data necessary for comprehensive SFM - this measure delegated tasks to competent employees, thus relieving the production manager from the task of processing the necessary data.

Conversion of visual board to a digital board with a touch screen monitor - as mentioned above, the SFM workplace at

the production manager level is combined with the segment manager's workplace. This workplace was equipped with two monitors (Figure 6b), one of which is a touch screen. Data on the digital board can be updated by pressing the "update" button without the need for intervention by the production manager.

Figure 6. Digitalization of SFM indicators at the level of a) team leader b) production/segment manager [Vizvary 2022]

The proposed measures were implemented in the analyzed company, significantly improving the functioning of the entire production area at various management levels within the examined S3 segment.

4.3 *Feedback on the digitalization of shop floor management in an industrial enterprise*

To evaluate the implemented measures, a questionnaire was created for the four levels of shop floor management. Employees from different segments who participate in SFM meetings were randomly selected to represent each level. The fourth and highest level in the management organizational structure, consisting of 7 managers, also took part in evaluating the digitalization of SFM. Even though these managers were not included in the workday snapshot process (since they do not participate in data collection and processing for SFM), their role is to make appropriate decisions and manage the company based on the data and information obtained within SFM. Therefore, they were included in the questionnaire survey focused on assessing the digitalization of SFM in segment S3.

The questionnaire consisted of three main questions:

1. What are the biggest advantages of dSFM in segment S3?
2. What are the biggest disadvantages of dSFM in segment S3?
3. Are the chosen KPIs sufficient for managing and controlling goal achievement within segment S3?

Respondents were given several answer options for each question (they could choose multiple answers) or add their observations and suggestions. For level 1 (workplace level), 12 randomly selected production workers responded; for level 2 (team leader level), 11 team leaders responded; for level 3 (production manager level), 10 technical employees responded; and for the highest level 4 (segment manager level), all 7 managers at this level participated.

For the purposes of this publication, only the most important findings from the questionnaire survey will be described.

Employees from levels 1, 2, and 4 consider the greatest advantage of dSFM to be the ability to monitor the status of machines and equipment in real-time (level 1: 33.33%; level 2: 20%; level 4: 24.43%). Employees fully recognize that real-time data enables more efficient control and faster reaction to problems occurring in the workplace. Production managers see the biggest benefit of dSFM (18.87%) in reducing the time spent walking around the plant to collect data for SFM, which, according to the workday snapshot, took up 16.35% of the production manager's total working time. Managers at the highest, fourth level of management see the benefit of dSFM in the ability to access the system while working from the home office (24.43%).

The second question concerned the most significant disadvantages brought by dSFM in segment S3. In this case, the responses varied across the different management levels. At the workplace level, up to 35% of employees found the process of filling out documentation more challenging when production issues were detected. This was due to increased demands on production workers in cases of deviations, which required the use of multiple methods (e.g., 5Why and others), ultimately extending the time needed to complete the required documentation. Surprisingly, employees at the second level of management (team leader level) considered the previous training on working with the SFM software insufficient (36.37%). This response confirms the importance of feedback. In this case, while the digitalization of SFM was technologically covered, the problem lay in insufficient training of employees on how to use the new software. At the third level of management, the most significant disadvantage of dSFM was the extended time spent on the PC (47.67%), related to technical issues with MES. Company managers consider the high setup costs of dSFM (42.85%) to be the biggest disadvantage, due to their responsibility for the segment's finances.

The third and final question of the survey focused on the suitability of the optimized KPIs used in SFM. While employees at levels 2, 3, and 4 are satisfied with the current optimized KPIs (level 2: 90.91%; level 3: 90%; level 4: 71.43%), employees at the workplace level selected the answer "I don't know" in 58.33% of responses. This revealed that production operators are unable to determine the importance of established KPI indicators and do not see their direct connection to specific problems. Based on the questionnaire survey, the company's management recognized this issue and planned regular meetings of employees with team leaders to explain the importance of KPIs and their impact on achieving the plan based on dSFM.

4.4 *Proposal for the digitalization process of shop floor management in an industrial enterprise*

The case study focused on digitalization has provided a wealth of information about the challenges a company faces when implementing such a complex process. The digitalization of SFM in the context of Industry 4.0 represents a significant challenge for the company, not only related to the implementation of the right technology but also to the human factor that will manage, direct, or process the data provided by these technologies. The implementation of dSFM is a complex process that requires careful planning, effective communication, engagement at all levels of the company, and continuous improvement. Employee education plays a crucial role in successful implementation,

ensuring that employees are prepared and able to effectively use new systems and technologies.

There has also been considerable interest in the digitalization of SFM from other departments within the analyzed company. Based on the case study of segment S3, the main problems to avoid when implementing dSFM in other segments have been identified. Figure 7 outlines six essential steps that we recommend for the introduction of dSFM in other segments of the company. This set of steps includes an analysis of the current state, technology selection, process integration, employee training, implementation itself, and subsequent optimization.

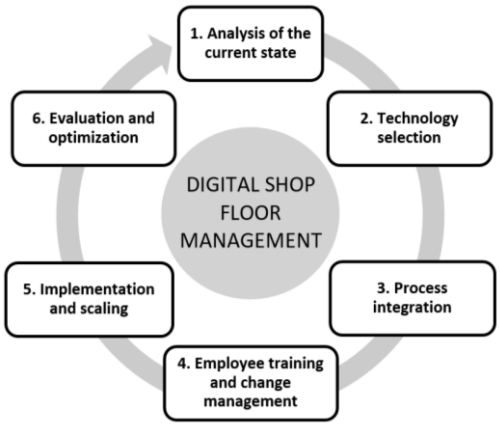


Figure 7. Steps for implementing digital shop floor management in an industrial enterprise

1. Analysis of the current state - this step involves a comprehensive assessment of existing processes on the production line, including data collection methods, communication channels, and management systems. It is necessary to identify bottlenecks and inefficiencies, such as errors in manual data entry, lack of real-time information, delays in decision-making, and the appropriateness of current KPIs. Part of the first step in implementing dSFM is to set clear objectives for dSFM implementation, such as improving operational efficiency, reducing downtime, or enhancing data accuracy.

2. Technology selection - the second step focuses on choosing software and hardware. It is essential to select software solutions that meet the specific needs of the company, such as Manufacturing Execution Systems (MES), data analysis platforms, IoT devices, and real-time monitoring tools. Ensure the modularity of the software and its ability to integrate with existing systems. Select the necessary hardware, such as sensors, IoT devices, and mobile devices for operators. Implement a pilot project to test the chosen technology in a controlled environment. Collect feedback from users and make necessary adjustments before full-scale implementation.

3. Process integration - automate data collection from various sources, such as machines, sensors, and quality control devices, to ensure accurate and real-time information flow (If Else Cloud). Set up centralized data dashboards for easy access and analysis by management and employees on the production line. Subsequently, develop Standard Operating Procedures (SOPs) for data entry, analysis, and reporting to maintain consistency across the company.

4. Employee training and change management - the fourth step focuses on the human factor, which drives the entire digitalization process. First, design comprehensive training programs to educate employees about the new tools and dSFM processes. This includes practical training, workshops, and ongoing education opportunities. Focus on key areas such as the significance of individual KPI indicators, data entry, analytics interpretation, and using digital dashboards. Determine whether the company can cover these trainings internally or if external experts are needed.

5. Implementation and scaling - the implementation of the dSFM system should be gradual. It is advisable to start with critical areas and gradually expand the system to other parts of the production line. Carefully monitor the implementation, collect data, and feedback for iterative improvements using Kaizen workshops and regular process evaluations. Foster a culture of continuous improvement, where employees are motivated to contribute ideas and solutions for ongoing enhancements. Utilize real-time data to identify areas for continuous improvement.

6. Evaluation and optimization - the success of dSFM implementation should be evaluated by comparing performance metrics with the set KPIs. Conduct regular audits to ensure adherence to new processes and identify areas requiring further optimization. Obtain feedback from users and stakeholders and use it to refine and enhance the system. Don't forget to update training programs and standardized procedures as needed to reflect any changes or improvements made during the implementation process.

5 CONCLUSIONS

Digitalization of SFM involves utilizing digital technologies to optimize and streamline production processes, increase efficiency, and improve overall manufacturing performance. This transformation is part of the broader industrial trend known as Industry 4.0, which emphasizes integrating digital technologies into manufacturing to create smart factories. Industrial companies' interest in digitalizing SFM is continually growing and is becoming essential to maintaining a competitive market position.

A case study focused on the digitalization of Shop Floor Management (dSFM) in a selected industrial enterprise revealed that successful implementation of digitalization within the Industry 4.0 framework requires not only technological solutions but also significant attention to the human factor. Identified issues and recommended steps provide valuable insights for further phases of dSFM implementation and have formed the basis for the six-step process that can be applied in any industrial company. The digitalization process must be meticulously planned and encompass all levels of the enterprise, from initial analysis through technology selection and process integration to employee training and continuous optimization. Key to success are effective communication, employee engagement, and the support of a culture of continuous improvement. This approach enables businesses to better manage the challenges of digitalization and achieve higher operational efficiency, quality, and flexibility in manufacturing processes.

Based on the results presented in this paper, the authors will focus their future research on the integration of artificial intelligence (AI) within dSFM. The integration of AI into dSFM has the potential to significantly transform production management by enhancing efficiency, quality, and flexibility. AI enables predictive maintenance, process optimization, automated decision-making, improved quality control, personalized employee training, and increased workplace safety. Additionally, it enhances data transparency and visualization, supporting a culture of continuous improvement. Overall, AI can provide substantial benefits to companies, allowing them to better respond to challenges and dynamically adapt to changing market conditions.

ACKNOWLEDGMENTS

This paper was written as a part of the project KEGA 026STU-4/2023 “Implementation of innovative learning methods and practical training to education in the field of production technologies and production management to increase the attractiveness of the students”.

REFERENCES

[Abdelmajied 2022] Abdelmajied, F.Y. Industry 4.0 and its implications: Concept, opportunities, and future directions. In Supply Chain-Recent Advances and New Perspectives in the Industry 4.0 Era. IntechOpen, 2022.

[Bertagnolli 2022] Bertagnolli, F. Lean management: Introduction and in-depth study of Japanese management philosophy. Springer Nature, 2022. ISBN 978-3658360863.

[Clausen 2018] Clausen, P., Mathiasen, J.B., Nielsen, J.S. Barriers and enablers for digitizing shop floor management boards. In: 2018 Global Wireless Summit (GWS), IEEE, November 2018, pp. 288-293. DOI: 10.1109/GWS.2018.8686591.

[Clausen 2020] Clausen, P., Mathiasen, J.B., Nielsen, J.S. Smart manufacturing through digital shop floor management boards. Wireless Personal Communications, 2020, Vol. 115, No. 4, pp. 3261-3274.

[Clausen 2021] Clausen, P., Henriksen, B. Teaching old dogs new tricks-towards a digital transformation strategy at the shop floor management level. In: Proceedings of the 8th Changeable, Agile, Reconfigurable and Virtual Production Conference (CARV2021) and the 10th World Mass Customization & Personalization Conference (MCPC2021); Aalborg, Denmark. Springer International Publishing, 2021, Vol. 8, pp. 746-753. DOI: 10.1007/978-3-030-90700-6_85.

[Clausen 2023] Clausen, P. Towards the industry 4.0 agenda: Practitioners' reasons why a digital transition of shop floor management visualization boards is warranted. Digital Business, 2023, Vol. 3, 100063.

[Dewald 2021] Dewald, M., et al. Using gamification on the shop floor for process optimization in machining production. MM Science Journal, 2021, Vol. November. pp. 5154-5159. DOI: 10.17973/MMSJ.2021_11_2021172.

[Dyadyura 2021] Dyadyura, K., Hrebenyk, L., Krenicky, T., Zaborowski, T. Modeling of the Manufacturing Systems State in the Conditions of the Lean Production. MM Science Journal, 2021, Vol. June, pp. 4408-4413.

[Elnadi 2024] Elnadi, M., Abdallah, Y.O. Industry 4.0: critical investigations and synthesis of key findings. Management Review Quarterly, 2024, Vol. 74, No. 2, pp. 711-744.

[Gisi 2023] Gisi, P.J. Fundamentals of Daily Shop Floor Management: A Guide for Manufacturing Optimization and Excellence. CRC Press, 2023. ISBN 978-1032370545.

[Grundnig 2018] Grundnig, A., Meitinger, S. Production Cockpit 4.0: The Shop Floor Management System of the Future. Zeitschrift fur wirtschaftlichen Fabrikbetrieb, 2018, Vol. 113, No. 12, pp. 873-877. DOI: https://doi.org/10.3139/104.112028.

[Halevi 2017] Halevi, G. Expectations and Disappointments of Industrial Innovations. Cham: Springer, 2017. ISBN: 978-3-319-50701-9.

[Chen 2022] Chen, T.C.T., Wang, Y.C. AI applications to shop floor management in lean manufacturing. Artificial Intelligence and Lean Manufacturing, 2022, pp. 75-90. DOI: 10.1007/978-3-031-04583-7_5.

[Iuga 2017] Iuga, M.V., Rosca, L.I. Comparison of problem solving tools in lean organizations. MATEC Web of Conferences, 2017, Vol. 121, 02004.

[Jamwal 2021] Jamwal, A., Agrawal, R., Sharma, M., Giallanza, A. Industry 4.0 technologies for manufacturing sustainability: A systematic review and future research directions. Applied Sciences, 2021, Vol. 11, No. 12, 5725.

[Kandler 2022] Kandler, M., et al. Shopfloor management acceptance in global manufacturing. Procedia CIRP, 2022, Vol. 115, pp. 190-195.

[Klein 2021] Klein, L.L., Tonetto, M.S., Avila, L.V., Moreira, R. Management of lean waste in a public higher education institution. Journal of Cleaner Production, 2021, 286: 125386.

[Kmec 2018] Kmec, J., Karkova, M., Majernik, J. Planning manufacturing processes of surface forming within Industry 4.0. MM Science Journal, 2018, Vol. December, pp. 2680-2685.

[Kumar 2022] Kumar, N., et al. Lean manufacturing techniques and its implementation: A review. Materials Today: Proceedings, 2022, Vol. 64, pp. 1188-1192.

[Lakshmanan 2023] Lakshmanan, R., Nyamekye, P., Virolainen, V.M., Piili, H. The convergence of lean management and additive manufacturing: Case of manufacturing industries. Cleaner Engineering and Technology, 2023, Vol. 13, 100620.

[Lemstra 2023] Lemstra, M.A.M.S., de Mesquita, M.A. Industry 4.0: A tertiary literature review. Technological Forecasting and Social Change, 2023, Vol. 186, 122204.

[Liu 2023] Liu, H.C., Liu, R., Gu, X., Yang, M. From total quality management to Quality 4.0: A systematic literature review and future research agenda. Frontiers of Engineering Management, 2023, Vol. 10, No. 2, pp. 191-205.

[Makysova 2024] Makysova, H., Galgoci, F., Gyurak Babelova, Z., Starecek, A. The improvement of the production process performance through material flow and storage efficiency increases serial production. Acta Logistica, 2024, Vol. 11, No. 1, pp. 57-65.

[Materna 2019] Materna, L., Hinrichsen, S., Adrian, B., Schulz, A. How to improve shop floor management. In: Production Engineering and Management. Padoano, E. & Villmer, F.-J. (eds.). Lemgo, 2019, pp. 179-188.

[Meissner 2018] Meissner, A., Muller, M., Hermann, A., Metternich, J. Digitalization as a catalyst for lean production: A learning factory approach for digital shop floor management. Procedia Manufacturing, 2018, Vol. 23, pp. 81-86.

[Meissner 2020] Meissner, A., Grunert, F., Metternich, J. Digital shop floor management: A target state. Procedia CIRP, 2020, Vol. 93, pp. 311-315.

[Moica 2020] Moica, S., Ganzarain, J., Ibarra, D., Ferencz, P. Change made in shop floor management to transform a conventional production system into an" Industry 4.0": Case studies in SME automotive production manufacturing. In: 7th International

Conference on Industrial Technology and Management (ICITM 2018); IEEE, 2018, pp. 51-56. DOI: 10.1109/ICITM.2018.8333919.

[Muller 2021] Muller, M., Alexandi, E., Metternich, J. Digital shop floor management enhanced by natural language processing. Procedia CIRP, 2021, Vol. 96, pp. 21-26.

[Oborski 2018] Oborski, P. Integration of machine operators with shop floor control system for Industry 4.0. Management and Production Engineering Review, 2018, Vol. 9, No. 4, pp. 48-55.

[Paramawardhani 2020] Paramawardhani, H., Amar, K. Waste identification in production process using lean manufacturing: A case study. Journal of Industrial Engineering and Halal Industries, 2020, Vol. 1, No. 1, pp. 39-46.

[Perianes-Rodriguez 2016] Perianes-Rodriguez, A., Waltman, L., Van Eck, N.J. Constructing bibliometric networks: A comparison between full and fractional counting. Journal of Informetrics, 2016, Vol. 10, No. 4, pp. 1178-1195.

[Potters 2018] Potters, P., Schindler, P., Leyendecker, B. Status quo Shopfloor Management. ZWF, 2018, Vol. 113, pp. 522-525.

[Richnak 2022] Richnak, P., Fidlerova, H. Impact and Potential of Sustainable Development Goals in Dimension of the Technological Revolution Industry 4.0 within the Analysis of Industrial Enterprises. Energies, 2022, Vol. 15, No. 10, 3697.

[Saxby 2020] Saxby, R., Cano-Kourouklis, M., Viza, E. An initial assessment of Lean Management methods for Industry 4.0. The TQM Journal, 2020, Vol. 32, No. 4, pp. 587-601.

[Tauber 2019] Tauber, M., Gallmetzer, A., Rauch, E., Brown, C. A., Matt, D.T. Concept design of a digital shop floor information system for assembly operators in machine industry. MATEC web of conferences, 2019, Vol. 301, 00017.

[Torres 2020] Torres, D., Pimentel, C., Duarte, S. Shop floor management system in the context of smart manufacturing: a case study. International Journal of Lean Six Sigma, 2020, Vol. 11, No. 5, pp. 823-848.

[Vizvary 2022] Vizvary, Z. Proposal of optimization of Shop Floor Management on a selected segment in the Schaeffler Skalica company. Diploma Thesis; Slovak University of Technology in Bratislava, 2022.

[Wester 2022] Wester, L.C., Hitka, M. Shopfloor Management – A Tool of Lean Management. Management Systems In Production Engineering, 2022, Vol. 30, No. 3, pp. 238-245.

[Zhang 2021] Zhang, C., Chen, Y., Chen, H., Chong, D. Industry 4.0 and its implementation: A review. Information Systems Frontiers, 2021, pp. 1-11.

[Zondo 2020] Zondo, R.W. Influence of a shop floor management system on labour productivity in an automotive parts manufacturing organisation in South Africa. South African Journal of Economic and Management Sciences, 2020, Vol. 23, No. 1, pp. 1-8.

CONTACTS:

Jana Mesarosova, Ing., PhD.
Slovak University of Technology in Bratislava
Faculty of Materials Science and Technology in Trnava
Institute of Industrial Engineering and Management
Jana Bottu 2781/25, 91724 Trnava, Slovak Republic
+421905950689, jana.mesarosova@stuba.sk