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Human-centered Digital Shopfloor Management Implementation and Acceptance Model

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Abstract

In times of disruptive changes, fast, decentralized decisions are becoming increasingly important in reacting quickly to changing environmental conditions. The growing availability of sensor technologies enables real-time data and, therefore, real-time transparency about the entire production system of a company. This transparency about all production processes, current problems and the company's success factors at all hierarchical levels is indispensable for making fast decisions to address challenges arising from the disruptive environment. The Lean Management Philosophy, especially digital Shopfloor Management (dSFM), offers many potentials for the realization of decentralized decisions and flat hierarchies in manufacturing companies that support fast reactions. While many companies already deal with dSFM, small and medium-sized enterprises (SME), in particular, often face recurring problems during the transformation process. Common challenges include the diversity of design parameters, the definition of appropriate key performance indicators and associated targets, as well as engaging all employees to ensure a successful dSFM implementation. The approach supports companies in the human-centered implementation of dSFM. Therefore, this paper presents a standardized implementation process for dSFM that is combined with the Modular, dSFM Model and the dSFM Acceptance Model to facilitate successful implementation and long-term success. At the beginning of the process, a dSFM maturity assessment is used, to define the current and goal state of the company-specific dSFM. With the assessment, suitable and valuable dSFM elements as well as acceptance measures, can be selected and combined with the specific dSFM. The selected elements, their relationships and the acceptance factors affected determine the sequence of the transformation process for the dSFM. A case study was conducted with a German SME, where the presented process was applied and adapted.

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1. Introduction

Shopfloor Management (SFM) is one of the most popular leadership instruments in production [1]. The influences of digitalization are correspondingly large, and it is, therefore, a key driver for new dSFM solutions to support workers and management in production control as well as production planning [2]. The increasingly adaptive design of production systems always requires an increasingly flexible design of the work system for employees. Due to the required very fast reaction times to change requests from customers, but also due to the increasing disruptions of supply chains, changes to the order sequence must be made frequently as part of daily production control [3]. Another example of the necessity for quick decisions is the distribution of tasks among employees and the implementation of work processes [4]. If employees have transparency regarding the required delivery dates, machine utilization and resource

availability, it is conceivable that employees will independently plan their capacity as well as their deployment to tasks. Daily SFM provides great support but requires a reliable data basis [5]. Accordingly, digitalization, especially the increasingly inexpensive sensor technology, offers great opportunities for generating a variety of production and process data. However, this data must be prepared, processed and visualized in a meaningful way in order to provide reliable information [4].

Today, there are already many recommendations for the digitalization of production systems towards smart factories. However, there is still a lack of concrete assistance for companies, particularly when it comes to adapting SFM to digitalization and increasingly complex production systems. Accordingly, the elements in SFM, such as documentation, knowledge sharing, and visualization tools, must also be adapted to digital technologies [6]. There are many solutions to support the SFM like Machine Learning, Artificial Intelligence or Smart Devices [4]. However, this abundance of technological upgrades and poten-

tial innovation poses challenges for companies similar to those faced during the implementation of Industry 4.0.

Therefore, companies must be supported in the sustainable implementation of dSFM. For this purpose, the "Modular, dSFM Model" developed by Kandler et al. [4] is extended to support companies in the practical selection and implementation of individual SFM elements in order to sustainably support the digitalization of SFM in companies. In addition, the acceptance model developed by Kandler et al. was included [7].

Section 2 presents existing approaches and relevant works. Section 3 briefly introduces the models developed by Kandler et al. that serve as the basis for the dSFM implementation strategy developed in this paper. Section 4 presents the implementation strategy step by step, and its practical application is explained in Section 5. Finally, Chapter 6 provides a summary and outlook.

2. Digital Shopfloor Management Models

Although the SFM is one of the best-known leadership instruments with a common philosophy, its individual design in companies is just as diverse as the companies themselves [8]. According to the individual company-specific design of the SFM, an implementation approach has to consider the variety of SFM elements [4] and structure them in a SFM-Toolbox. In addition, different maturity levels of digitalization determine the expansion of SFM in companies [9]. Furthermore, the selection of the SFM elements has an influence on the realization of the SFM targets, which is why the target relationships between the SFM elements and the SFM targets must be addressed during implementation [5].

In order to combine individual SFM elements in a targeted manner, a maturity assessment is suitable, with which the current and target state of the SFM can be evaluated, and suitable SFM elements can thus be selected for implementation. Accordingly, the implementation of SFM is a long process, which is why the implementation approach must be phased and iterative. In addition, the process should be practical and concrete, thus aiding in implementation [10]. The success factor in the rollout of SFM is the acceptance by employees [8]. Accordingly, the implementation procedure should address the acceptance factors of SFM and employees and include acceptance measures to achieve a high level of acceptance. These acceptance measures must be selected based on the situation. Regular and iterative evaluation of implementation success operationalizes employee acceptance and thus secures it in the long term.

2.1. Various Shopfloor Management Models

In the field of SFM, there exist numerous models that describe the use and benefit of SFM. Suzaki [11] and Bertagnolli [8] focus on the philosophy of the SFM in combination with the Lean Leadership Principles. A more technological focus on the SFM elements is given by Hertle et al. [12] and Domrowski et al. [13]. Both of them highlight visual management, the key performance indicators, and problem-solving management as the most important parts of SFM. Hertle also describes

the benefit of SFM for the competence development of employees [12]. New approaches like Meissner et al. [5] and Lorenz et al. [6], focus on the digitalization of SFM with new technologies like Artificial Intelligence, Machine Learning or Natural Language Processing and show some development paths for the new dSFM. Clausen [14], Longard [15], and Müller [16] focus on individual elements of SFM and describe their impact on SFM as well as their changes through digitalization. Although many types of individual SFM elements exist, Kandler et al. [4] developed a first toolbox in their "Modular, Digital SFM Model", which summarizes the different SFM elements in a structured manner.

2.2. Maturity Assessment and Implementation Strategies for Shopfloor Management

dSFM is a part of Industry 4.0. Therefore, existing implementation strategies for Industry 4.0, like those of Liebrecht et al. [2] or Schuhmacher et al. [17], could constitute possible approaches for implementing dSFM in companies. Maturity models offer support in determining the current and target status for the implementation of dSFM. The maturity assessment of Schuhmacher et al. [17] evaluates companies in a total of 14 Industry 4.0 dimensions. Accordingly, this model can be used as a template for a maturity model for dSFM but must be adapted. Bock et al. [9] define four different maturity levels for the digitalization of SFM and give concrete explanations for achieving each target state. Another possible approach is concrete guidelines, such as the approach of Conrad et al. [18], which facilitate a concrete SFM implementation by embedding the SFM elements in a step-based implementation process. Other examples of such concrete implementation guidelines are the approaches of Peters [19] and Leyendecker [20].

2.3. Acceptance of Shopfloor Management

The greatest success factor of dSFM is the acceptance of employees and an appropriate change management (CM) [8]. CM supports the implementation of new technologies while considering the requirements of the employees in order to achieve acceptance. The research of Ullrich et al. [21], Bateh et al. [22] as well as Long and Spurlock [23] are examples of socio-technical approaches to define a CM Process. Acceptance factors, as described in Davis' Technology Acceptance Model [24], form the basis for mainly all acceptance models and CM in production. Sorko et al. [25], Molino et al. [26], and Bretz et al. [27] use these models to support the introduction of Industry 4.0 due to the many obstacles in the digitalization of production. Kopp et al. [28], on the other hand, get even more specific and focus on an acceptance model for human-robot collaboration, explaining specific measures to create acceptance. The acceptance factors identified in this context are also the basis for the acceptance model for dSFM developed by Kandler et al. [7] or Clausen et al. [14].

3. Modular, Digital Shopfloor Management Model and Acceptance Model for Digital Shopfloor Management

The approach proposed in this work (see Section 4) for human-centered dSFM implementation is based on the two models developed by Kandler et al. (see Figure 1): the Modular, dSFM Model [4] and the Acceptance Model for Digital Shopfloor Management [7].

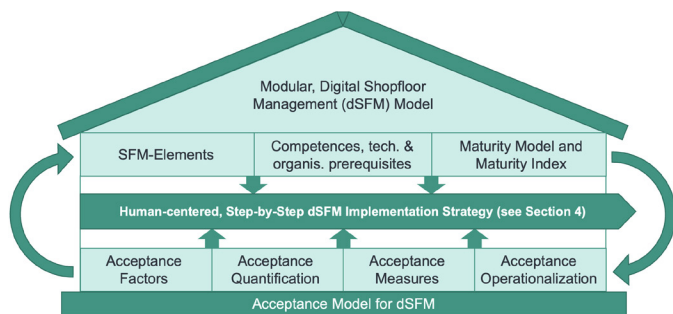


Fig. 1. Existing models as the basis for the dSFM implementation strategy

The dSFM Model comprises two main fields: "dSFM Enablers" and "dSFM Potentials". These fields consist of a total of six cross-sectional dimensions and are associated with 13 SFM categories. The model also takes into account employee acceptance and qualifications. To enhance the model, a maturity index was created with the four maturity levels: Analogue, Digitized, Digital/Connected, and Smart/Autonomous. The dSFM model includes a total of 90 SFM elements assigned to the individual SFM categories. Each SFM element has its own profile with various information on expected impacts and benefits for SFM. In addition, the profiles comprise factors that facilitate the effective execution of the corresponding element for individuals and production. These factors include essential employee competencies (e.g. data analysis skills), technical requirements (e.g. data collection sensors), and approaches to acceptance requirements (e.g. usability). Furthermore, each SFM element is assigned to a maturity level [4].

The dSFM Acceptance Model evaluates and explains SFM's acceptance, using targeted employee surveys to increase acceptance. The model's five-step acceptance improvement process involves standardizing survey items, conducting local employee surveys, determining current acceptance levels, setting acceptance increase targets, and selecting appropriate acceptance measures. The modular design of the model enables standardized acceptance measures to be tailored to different teams and production sites for an individualized approach. Profiles for acceptance activities, such as training and workshops, were developed to promote SFM change acceptance, providing instructions and necessary materials [7].

As part of an online literature review, the target dimensions of dSFM were researched and added to the profiles of the SFM elements (see Figure 2) [2, 13, 18, 20, 29, 30, 31, 32]. During an expert interview, rating points were assigned to all target dimensions for each SFM element. The rating scale ranges from -3 (strong deterioration of the target dimension) to +3 (great improvement of the target dimension) [2]. In addition, the im-

plementation effort was considered. Since the target dimension "implementation effort" cannot be positive [2], the scale here ranges from -3 to 0 (no impact).

Target dimensions of dSFM:		
Process execution [2,30]	Process improvement [28,29,16,30]	Employee development [29,30,11]
Achievement of corporate goals [29,18,11]	Sustainable introduction of new processes [28,29]	Build employee/leadership skills [28,29,30,11]
Sustainable customer satisfaction [18]	Standardization [28,18,31,11]	Sustainable employee productivity through ergonomics, occupational safety, acceptance, satisfaction and motivation [18,30,11]
	Drive improvement projects [29,18,11]	
Months [2]		
Fulfillment of customer orders / customer satisfaction [29,18]	Recognize deviations and solve problems [28,29,16,18,11]	
Improve key performance indicators (e.g., delivery capability) [29,18,30,11]	Structured approach [16,18,30,11]	
	Involve employees/participation [28,29,16,18,30,31,11]	
Day - week [2]		
Creation of transparency/visualization [16,18,30,11]	Occupational safety [32]	
Hour - day [2]		
Secure capacities/output [29,18]	Stabilization of processes [28,29]	Use of appropriately qualified employees [28,29]
Quality (e.g., reduce scrap and rework) [29,18,31]	Fast and uncomplicated problem solving on site [4,11]	Improve morale/motivation on a daily basis [18,30]
Flexibility (e.g., increase volume flexibility) [32]	Timely interaction (commun.) for decision making [11]	Employee self-management/ self-organization [18,31,11]
Time (e.g. reduce setup time) [29,18]		
Costs (e.g. increase resource productivity) [18,32]		

Fig. 2. Target dimensions of SFM elements

4. Own Approach

In this paper, an overall concept for the maturity assessment and the implementation of the dSFM is developed based on Bruin and Rosemann's framework that outlines the main phases of developing a maturity assessment model [33].

Our approach involves a maturity assessment to describe the as-is state of the company and to identify the to-be state (vision) (see Figure 3). Based on the maturity assessment, a gap analysis is conducted to derive an implementation strategy for enhancing the dSFM from the current state to the target state. We realized the maturity assessment in two different tools. The first is an online self-assessment tool called "Quick Check", which provides a preliminary self-assessment of the organization's dSFM maturity level and vision, along with simple recommendations for improving the maturity level [4]. The second tool, called "Detail Check", allows for a detailed assessment of each of the 13 SFM categories, the current state, and the development of a human-centered implementation strategy.

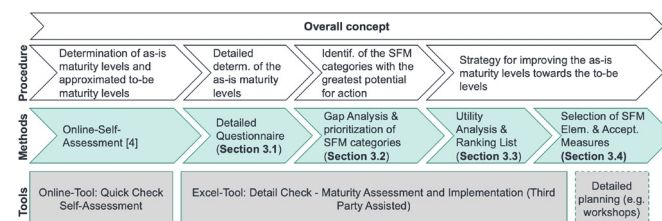


Fig. 3. Overall concept from as-is analysis to implementation planning

4.1. Detailed Questionnaire

To assess the maturity level of a SFM category, a detailed questionnaire is used to analyze the implementation level (IL) of each SFM element within that SFM category. The IL is classified using the levels Initial, Planned, Defined, Measurable, and Optimizing [34]. The IL "Initial" means that the SFM element is not being applied, while the highest IL "Optimizing" is achieved when the SFM element is being optimally utilized. The following procedure is shown in Figure 4.

The questionnaire first asks yes/no questions to determine if the organizational and technical prerequisites of each SFM element are fulfilled (step "1."). If the prerequisites are not fulfilled, the IL is "Initial", which corresponds to a maturity level of zero. If the prerequisites are fulfilled, the fulfillment of the properties of the SFM element is queried and each property is assigned to an IL (step "2."). This ensures that not only the prerequisites are met, but also that the SFM element is actually being applied. The IL of the SFM element is determined by the average IL of all properties with equal weighting (step "3."). This procedure is repeated for all SFM elements of the SFM category (step "4."). A particular maturity level is achieved by a SFM category when all SFM elements assigned to that maturity level have reached at least IL "Planned", and the SFM elements of all lower maturity levels have also reached at least IL "Planned" (step "5."). The IL of a SFM category is calculated as the average IL of all SFM elements and is used to determine the extent to which the maturity level of a SFM category has been achieved (step "6."). For example, if the maturity level of a SFM category A is assigned as "Analogue" (Level 1) and the IL of SFM category A is "Defined" (50%), then the actual maturity level of category A is only 50% of "Analogue," and lies exactly between Level 0 and Level "Analogue" (step "7.").

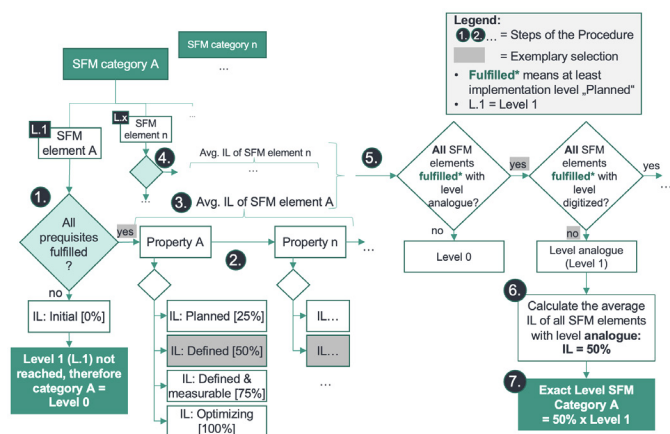


Fig. 4. Procedure for determining the maturity level based on an example

4.2. Gap Analysis and Prioritization of Shopfloor Management Categories

Once the maturity levels have been established for all SFM categories, the gaps in maturity for each SFM category can be identified. This is done by calculating the disparity between the

current and target maturity levels for each SFM category. Then, the SFM categories are prioritized based on the magnitude of the calculated difference between current and target maturity levels. A higher priority is assigned to the categories with the largest difference, indicating a greater need for action. SFM categories with a difference of less than or equal to 0.5 require no immediate development measures [17].

4.3. Utility Analysis and Ranking List of Shopfloor Management Elements

After identifying the SFM category with the greatest gap between its current and desired target level, the SFM elements within this category that have not yet been implemented in the organization are evaluated [35]. The evaluation of the SFM elements is conducted with a utility analysis and forms the basis for deciding which elements to implement and in what order. As criteria for the utility analysis, the SFM target dimensions and implementation effort of each SFM element is used (see Figure 2). The weighting of the target dimensions of each SFM element is done by Analytic Hierarchy Process (AHP) method using the 9-point scale of Saaty [36]. The tool calculates the utility values of each SFM element to be implemented. This ranking list provides an overview of all SFM elements, sorting them based on their greatest contribution to achieving the dSFM target state while considering the organization's individual preferences.

4.4. Selection of Shopfloor Management Elements and Acceptance Activities

In a further step, the tool allows the selection of the SFM element to be implemented first. The tool offers the user the freedom to decide on the implementation order without being constrained to choose the SFM element with the highest utility value. This allows the user to have more flexibility and control in determining the implementation sequence.

After a SFM element is selected, the user estimates the desired start date as well as the implementation duration. The ranking list is automatically updated, and the selection of the next SFM element to be implemented follows. This procedure ends when there are no more SFM elements to be implemented in the ranking list, i.e. when all SFM categories meet the desired maturity level. This is followed by the selection of suitable organizational prerequisites, including the start date and implementation period. Examples for these include the creation of standardized processes [11, 37] and efficient, targeted, and regulated communication [18, 37, 20]. The implementation of dSFM requires a socio-technical implementation approach that takes into account people, technology and organization [10], which has been integrated into the tool.

After the selection of SFM elements, an employee survey is conducted to measure the acceptance (quantification in the Acceptance Model) of the technology, organization, and human readiness. The tool facilitates the selection of appropriate acceptance activities based on the results of the employee survey to improve the readiness for implementation. Furthermore, ad-

ditional acceptance measurements take place prior to and during the implementation at the so-called Implementation Gates (IG) [10]. The tool enables individual scheduling of the IG. The selected acceptance measures are transferred into the Gantt chart, taking into account the duration of their execution (see Figure 6). The final report includes a Gantt chart outlining the major milestones and pre-determined implementation activities required to achieve the desired dSFM target state. This implementation strategy can be refined through an iterative process to ensure a successful start to the implementation phase.

5. Results

The overall concept was tested at a German SME in December 2022 with a dSFM expert, a production employee and the production manager. In the beginning, the production employee and the production manager performed the Quick Check. The results show that the largest gap between the to-be and as-is maturity level was in the SFM categories of "KPI Visualization", "Continuous Improvement Process", and "Documentation". Participants decided to examine the three SFM categories with the largest gaps between as-is and target maturity levels during the Detail Check. Target maturity levels from the Quick Check were transferred to the Detail Check. The dSFM expert used the questionnaires in the Detail Check to determine the IL of each property, and results showed that "Documentation" had the largest maturity gap, followed by "KPI visualization" and then "Continuous Improvement Process." (see Figure 5).

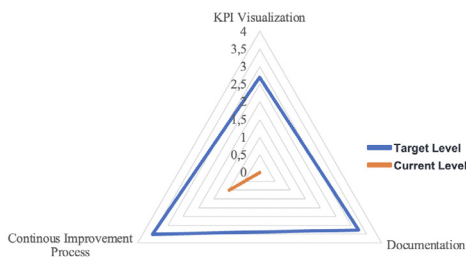


Fig. 5. Resulting maturity levels of three dimensions from Detail Check

Subsequently, the participants used the AHP to define the weights for the utility analysis. This involved pairwise comparisons of the dSFM target dimensions and implementation effort. The dSFM expert asked about the importance of each criterion in relation to the others, which allowed the tool to calculate the weightings. The SFM elements were then ranked so that the SFM elements and utility values could be seen in priority order. The SFM element "Analogue Documentation" had the highest utility value and, thus, the highest priority. In order to prioritize the SFM elements, a ranking based on their utility values was conducted. As a result, the SFM element "Analogue Documentation" was found to have the highest utility value and was consequently given the highest priority for implementation.

The participants analyzed the utility rankings and selected "Analogue Documentation" as the first SFM element to implement on February 1st, 2023, with an estimated implemen-

tation duration of four weeks. Additional methods were scheduled from the ranked list until all methods were selected. Organizational prerequisites were checked for each element and added to the Gantt chart if not met, with the estimated implementation start date and duration. The participants chose the timing of IG0 and subsequent IG and selected acceptance measures, such as "Business Origami". The start date and duration were specified for each acceptance measure (see Figure 6). The tool provided a report with all relevant information for detailed planning of the implementation activities. Additionally, it was demonstrated through employee surveys that the application of acceptance measures increases employee acceptance.

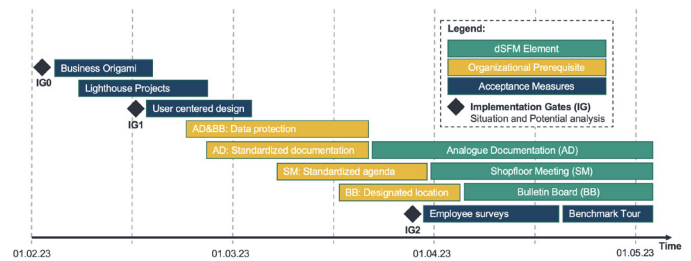


Fig. 6. Extract from the Gantt chart with the defined implementation sequence

6. Conclusion and Outlook

The Lean Management Philosophy, with a focus on dSFM, has the potential for decentralized decision-making and flat hierarchies in manufacturing companies, enabling quick reactions. However, the transformation to dSFM often fails when it comes to developing a suitable company-specific implementation strategy of (d)SFM elements that should take acceptance into account. Our developed concept enables the assessment of the current maturity level of dSFM and the identification of priority SFM categories for action. It also supports the definition of an appropriate implementation strategy to bridge the gap between the current and target maturity levels, with the sequence of SFM elements to be implemented based on a utility analysis tailored to the company's needs. The implementation process considers acceptance activities to ensure a human-centered approach. The resulting Gantt chart includes the SFM elements, organizational requirements, and acceptance activities. The concept was successfully tested with a SME in December 2022, using the online self-assessment Quick Check and third-party assisted Detail Check. Further research is needed to plan implementation in greater detail and investigate possibilities for technological innovation and best practice examples.

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