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Implementation Strategies for Intelligent Systems to Support Manufacturing Planning: Recommended Actions to Avoid Failure

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ABSTRACT

Intelligent support systems can help employees to quickly and efficiently carry out the increasingly complex process of manufacturing planning. However, since such systems tend to be used with restraint or at least inefficiently which may be due to insufficient implementation strategies, this paper examines how an implementation strategy for intelligent systems to support manufacturing planning could be designed. Based on a systematic literature review, success factors as well as recommendations for action for implementing digital support systems in manufacturing were identified and aggregated. In a survey with 31 experts with experience in implementing support systems in enterprises, the relevance of the recommendations for action for the long-term implementation success of intelligent support systems for manufacturing planning was evaluated. Additionally, their assignment to five phases of a generic implementation process model was assessed. This paper describes the methodological approaches and the results of both studies. The results show, e.g., that most of the recommendations concern the interaction with the employees affected. Furthermore, many of the recommended actions are important for most or even all phases of an implementation process.

Keywords: Implementation strategies, Intelligent support systems, Computer aided manufacturing

INTRODUCTION

In many manufacturing enterprises, manufacturing planning for the production of complex components is carried out by using CAM systems (CAM: Computer Aided Manufacturing) (Bi and Wang, 2020). The increasing complexity and individualization of components, tools and machines lead to new requirements for manufacturing planning and CAM systems (Suhl and Isenberg, 2019; Jayasekara et al., 2019). Providers of CAx systems and researchers are currently working on the further development of conventional support systems by incorporating artificial intelligence (AI) applications (e.g. Dripke et al., 2017). At the same time, studies in Germany (e.g. Lundborg and Gull, 2021; Merkel-Kiss and von Garrel, 2022) indicate

that available AI-based systems are generally rather used with restraint, especially by SMEs, or not used effectively, e.g., due to acceptance issues. Since a successful implementation of these systems requires appropriate strategies (Kletti, 2007; cf. Bellantuono et al., 2021; cf. Kovrigin and Vasiliev, 2020), insufficient implementation strategies could be a reason for the restraint. However, existing implementation strategies within the application context of manufacturing planning do not specifically focus on intelligent support systems, but rather on conventional digital ones in general. Therefore, recommendations for action for the implementation of digital support systems in manufacturing were identified and then evaluated in the context of intelligent systems to support manufacturing planning. Based on this, first implications are expected for the development and implementation of an intelligent CAM system in the research project CAM2030.

This paper addresses the research question of how to design an implementation strategy for intelligent support systems for manufacturing planning to ensure a successful implementation for the long term. An implementation strategy is understood as a plan for introduction, presented in the form of recommendations for action with reference to a procedural model (cf. Tarlatt, 2001). The scope of implementation is considered in a broad sense, from the definition of goals and the system selection to the continuous improvement of the introduced system. First, a systematic literature review was conducted to identify success factors and corresponding recommendations for action in the context of implementation strategies for digital support systems in manufacturing. Second, 31 experts with experience in implementing support systems in a corporate context were asked to assess the importance of these recommendations for the successful implementation of intelligent support systems for manufacturing planning in an online questionnaire. The questionnaire also included the assignment of the recommendations for action to phases of a generic implementation model.

In this paper, the procedure and the results of the literature review as well as the empirical study are presented. Finally, the resulting recommendations for action concerning the implementation of intelligent support systems for manufacturing planning and related limitations are discussed.

SYSTEMATIC LITERATURE REVIEW

In the following, the search and selection procedure as well as the results of the systematic literature review are presented.

Search and Selection Procedure

The literature review was conducted based on the STARLITE approach (Booth, 2006) complemented by the PRISMA statement (Page et al., 2021). The STARLITE elements were set as follows: The selective *sampling strategy*, no restriction regarding the *type of studies*, the *approach* electronic subject search, the *range of years* from January 2000 to October 2022, and the

functional *limits* to English and German-language publications as well as the manufacturing context as *inclusion* were applied. The *terms used* as search query was: (implementation OR launch OR introduction) AND strategy AND digital AND system AND (production OR manufacturing). As *electronic source*, the databases Scopus (Elsevier B.V.), IEEE Xplore (IEEE), and Web of Science (Clarivate) were used.

In the first step, the search resulted in a collection of 1182 papers. After removing duplicates (n = 227) as well as non-German and non-English publications (n = 27), 928 articles remained which were examined by reviewing title and keywords. In this step, 742 publications were excluded especially due to a missing reference to manufacturing or digital system context. By reviewing the abstracts of the remaining 186 publications, 133 publications were further excluded based on their relevance for the given context. Subtracting seven articles that could not be retrieved, 46 publications as well as two additional articles found through a manual reverse search were examined based on their full texts.

Identified Success Factors and Recommendations for Action for the Implementation of Digital Support Systems in Manufacturing

Success factors for the implementation of digital support systems in the manufacturing context were extracted and aggregated. The results were classified into four categories: *organization*, *people*, *technology*, and *data*. Table 1 shows the aggregated organization-related success factors and recommendations for action.

A flexible organizational structure can promote the implementation of digital technologies (Albukhitan, 2020). In this context, a multidisciplinary team structure with clear tasks and responsibilities is recommended for managing the implementation (Albukhitan, 2020; Bellantuono et al., 2021). Another success factor is the identification of short- and long-term

Table 1. Organization-related success factors and recommendations for action.

Factor with related recommendations for action	**Reference (Excerpt)**
Organizational structure	**Albukhitan, 2020**
O01: Assemble suitable team for the implementation	Albukhitan, 2020
O02: Clearly distribute implementation responsibilities and tasks	Bellantuono et al., 2021
Organizational goals for implementation	**Bellantuono et al., 2021**
O03: Identify short- and long-term goals for implementation	Bellantuono et al., 2021
Communication	**Albukhitan, 2020**
O04: Communicate information about the change taking place	Bellantuono et al., 2021
Capital	**Kovrigin and Vasiliev, 2020**
O05: Plan the investment process in detail	Albukhitan, 2020
O06: Make sufficient investment in staff (training, education etc.)	Kovrigin and Vasiliev, 2020

goals for implementation (Bellantuono et al., 2021). Changes resulting from implementation should be continually communicated to all affected employees to inform and promote technology acceptance (Albukhitan, 2020; Bellantuono et al., 2021).

From a financial perspective, the implementation requires sufficient investments not only in digital technology, but also particularly in employees (e.g. training) (Kovrigin and Vasiliev, 2020). In order to justify the investment, it should be planned in detail (Kovrigin and Vasiliev, 2020; Albukhitan, 2020).

The people-related results are presented in Table 2. When introducing digital systems, the training of employees involved is essential for avoiding resistance to change and thus for the implementation success (Bellantuono et al., 2021). Training programs should not only cover digital skills for operating the system, but also capabilities, e.g. for teamwork and effective communication (Bellantuono et al., 2021). In addition, training programs for the managers are seen as a promoting factor for the success of an implementation (Azevedo and Almeida, 2021). In the context of digital transformation in SMEs, Azevedo and Almeida (2021) present a management training program that includes technological insights as well as obstacles and opportunities for implementation.

Apart from training programs, a participatory and human-centered implementation approach that actively involves all affected employees is recommended (Bellantuono et al., 2021). To avoid implementation resistance, resistance must first be identified and then managed, e.g. by discussing the reasons, goals, benefits, and timetable with all employees involved

Table 2. People-related success factors and recommendations for action.

Factor with related recommendations for action	**Reference (Excerpt)**
Training of employees	**Bellantuono et al., 2021**
P01: Plan training programs for employees	Bellantuono et al., 2021
P02: Conduct training programs for employees	Bellantuono et al., 2021
P03: Adjust workload to create capacity for training programs	Shinohara et al., 2017
Training of managers	**Azevedo and Almeida, 2021**
P04: Plan training programs for managers	Azevedo and Almeida, 2021
P05: Conduct training programs for managers	Azevedo and Almeida, 2021
Participation	**Bellantuono et al., 2021**
P06: Involve affected stakeholders in implementation planning	Bellantuono et al., 2021
P07: Identify resistance to implementation	Bellantuono et al., 2021
P08: Managers show commitment	Albukhitan, 2020
Employees' motivation and acceptance	**Kandler et al., 2022**
P09: Ensure support by managers	Merhar et al., 2019
P10: Ensure simple operability	Merhar et al., 2019
P11: Ensure data protection, work safety, and data security	Merhar et al., 2019
External support	**Albukhitan, 2020**
P12: Consider collaboration with external consultants	Albukhitan, 2020
P13: Hire new employees with required competencies	Albukhitan, 2020

(Bellantuono et al., 2021). Additionally, the management should show high commitment and pass this on to employees as part of the digital transformation process (Albukhitan, 2020).

Employees' motivation and acceptance are critical success factors (Kandler et al., 2022). Thereby, a participatory implementation is considered as key influence on the acceptance of the system (Kandler et al., 2022). To promote acceptance, support from managers, a simple operability of the system, and ensuring data protection, work safety, and data security are recommended (Merhar et al., 2019). If the expertise available within the enterprise is not sufficient, external sources (consultants, hiring new employees) should be considered (Albukhitan, 2020).

The technology-related success factors and recommendations for action are shown in Table 3. Since the integration of digital systems into enterprises is hampered if digital solutions only replace single process steps, automating adjacent manual processes can facilitate the implementation (Albukhitan, 2020). Moreover, a successful implementation is enhanced if the digital transformation process includes several business activities (Albukhitan, 2020). In terms of technological requirements, the availability of suitable hardware is a critical success factor for system implementation (Shinohara et al., 2017).

Regarding data-related success factors and recommendations for action (Table 4), data availability and data management is a critical success factor for implementing digital systems in manufacturing (Shinohara et al., 2017). A data analytics strategy guides an effective data collection and analysis to support decision-making as well as enables the use of data-driven digital systems (Geissbauer et al., 2016; Shinohara et al., 2017). During the implementation process, feedback data should be collected and processed from stakeholders involved in the change in order to identify critical issues as basis for corrective actions (Bellantuono et al., 2021). Furthermore, stakeholders should be provided with sufficient information on the implementation process, e.g. regarding the roadmap (Bellantuono et al., 2021).

Another success factor addresses the data exchange between departments. This can be supported by reducing the variety of different systems for each department and enabling interoperability (Shinohara et al., 2017). Additionally, competitive thinking between departments should be reduced (Kovrigin and Vasiliev, 2020).

Table 3. Technology-related success factors and recommendations for action.

Factor with related recommendations for action	**Reference (Excerpt)**
Digital/automated processes	**Albukhitan, 2020**
T01: Automate adjacent manual processes	Albukhitan, 2020
T02: Digitize existing business processes	Albukhitan, 2020
Technological requirements	**Shinohara et al., 2017**
T03: Provide suitable hardware	Shinohara et al., 2017

Table 4. Data-related success factors and recommendations for action.

Factor with related recommendations for action	**Reference (Excerpt)**
Data availability and data management (collection/processing)	**Shinohara et al., 2017**
D01: Develop effective data analytics strategy	Geissbauer et al., 2016
D02: Collect and process feedback from people affected by change	Bellantuono et al., 2021
D03: Provide sufficient information on the implementation	Bellantuono et al., 2021
Data exchange between departments	**Shinohara et al., 2017**
D04: Reduce variety of different systems for each department	Shinohara et al., 2017
D05: Reduce competitive thinking between departments	Kovrigin and Vasiliev, 2020

EMPIRICAL STUDY

To evaluate the importance of the recommendations for action for a successful implementation of intelligent support systems for manufacturing planning, an online survey was conducted in October 2022.

Questionnaire Design

The study was implemented as an online questionnaire in the web application *SoSci Survey*®. The importance of the recommendations for action was assessed using a four-point scale (*1 = unimportant* to *4 = important*). For the evaluation, mean value (M) and standard deviation (SD) were determined.

Additionally, the respondents were asked to assign each recommendation to one or more phases of a generic implementation process model. Therefore, a model illustration and brief description based on the following five phases was presented:

- Phase 1: *Goal and selection* (determining the goal and purpose, and selecting the system to be implemented)
- Phase 2: *Planning* (planning the implementation)
- Phase 3: *Preparation for implementation* (preparing employees and workplace environment for the use of the system)
- Phase 4: *Implementation of the system* (actual system implementation)
- Phase 5: *Review and adjustment* (continuous review and adjustment of the system)

Description of the Sample

The online questionnaire was completed by 31 participants from Germany (6 female, 25 male). The age of the participants ranged from Minimum = 26 years to Maximum = 66 years (M = 42.19 years, SD = 11.47 years). The participants covered a variety of industries and all had experience with the implementation of digital or intelligent support systems in enterprises. Among others, the following professional titles were named: research

associate, management consultant, research manager, process manager, production engineer, IT manager, and software developer. Systems introduced included: *SAP S/4HANA®*, ERP systems in general, digital worker assistance systems, digital twins, *EXAPTsmartcontrol®*, CAx systems, or various monitoring systems.

Evaluation of the Recommendations for Action for the Implementation of Intelligent Systems for Manufacturing Planning

For the interpretation of the results (Table 5), the following assumptions were made: First, recommendations with $M < 2$ are not considered as important for the implementation success. Recommendations with $2 \leq M \leq 4$ are regarded as important. Second, a recommendation for action is assumed to be relevant for a phase if at least eight participants (25 %) assigned it to the respective phase. Only those phases are listed in Table 5.

Overall, the mean values (s. Table 5) show that all recommendations for action assessed are considered important for the implementation of intelligent support systems based on the assumption above ($2.55 \leq M \leq 3.81$). The SD values can be used to examine the dispersion of responses around the corresponding mean value, assuming the central limit theorem (Fahrmeir et al., 2016). Based on this, the results ($0.42 \leq SD \leq 1.01$) indicate a reasonably consistent assessment of relevance by the participants.

In the category *organization*, the mean values of all recommendations except for the detailed investment process planning (O05, $M = 2.94$, $SD = 0.72$) are higher than $M = 3$, indicating that they are considered at least rather important. Showing the highest assessed importance in relation to all recommendations, the assembly of a suitable implementation team appears to be particularly important (O01, $M = 3.81$, $SD = 0.47$). Also, the identification of short- and long-term goals seems to be important for implementation (O03, $M = 3.77$, $SD = 0.42$).

In the category *people*, only the consideration of external consultants (P12, $M = 2.55$, $SD = 0.66$) and hiring new employees (P13, $M = 2.68$, $SD = 0.82$) have mean values smaller than $M = 3$, indicating lower importance than the other people-related recommendations. Conducting employee training programs (P02, $M = 3.61$, $SD = 0.55$), involving stakeholders in the implementation planning (P06, $M = 3.68$, $SD = 0.64$), and a high commitment of managers (P08, $M = 3.71$, $SD = 0.68$) seem to be particularly important as they show the highest mean values within the category.

Regarding the technology-related results, the recommendation "provide suitable hardware" (T03, $M = 3.26$, $SD = 0.76$) was assessed as most important for the implementation success. According to the participants, the digitalization of existing business processes (T02, $M = 3.00$, $SD = 0.76$) is more important than the automation of adjacent manual processes (T01, $M = 2.61$, $SD = 0.83$).

Within the data-related recommendations for action, the participants considered the collection and processing of feedback from people affected (D02, $M = 3.55$, $SD = 0.56$) as well as the provision of sufficient information

Table 5. Descriptive statistics and allocation of phases.

Recommendation for action		M (SD)	Phases
O01	Assemble suitable team for the implementation	3.81 (0.47)	1, 2, 3, 5
O02	Clearly distribute implementation responsibilities and tasks	3.39 (0.61)	1, 2, 3
O03	Identify short- and long-term goals for implementation	3.77 (0.42)	1, 2
O04	Communicate information about the change taking place	3.48 (0.80)	1, 2, 3, 4, 5
O05	Plan the investment process in detail	2.94 (0.72)	1, 2
O06	Make sufficient investment in staff (training, education etc.)	3.26 (0.80)	1, 2, 3, 4, 5
P01	Plan training programs for employees	3.42 (0.71)	2, 3
P02	Conduct training programs for employees	3.61 (0.55)	3, 4, 5
P03	Adjust workload to create capacity for training programs	3.06 (0.84)	2, 3, 4, 5
P04	Plan training programs for managers	3.35 (0.82)	2, 3
P05	Conduct training programs for managers	3.39 (0.79)	3, 4, 5
P06	Involve affected stakeholders in implementation planning	3.68 (0.64)	1, 2, 3, 4, 5
P07	Identify resistance to implementation	3.26 (0.72)	1, 2, 3, 4, 5
P08	Managers show commitment	3.71 (0.68)	1, 2, 3, 4, 5
P09	Ensure support by managers	3.23 (0.83)	1, 2, 3, 4, 5
P10	Ensure simple operability	3.35 (0.74)	1, 2, 3, 4, 5
P11	Ensure data protection, work safety, and data security	3.55 (0.61)	1, 2, 3, 4, 5
P12	Consider collaboration with external consultants	2.55 (0.66)	1, 2
P13	Hire new employees with required competencies	2.68 (0.82)	2, 3, 4, 5
T01	Automate adjacent manual processes	2.61 (0.83)	2, 3, 4, 5
T02	Digitize existing business processes	3.00 (0.76)	1, 2, 3
T03	Provide suitable hardware	3.26 (0.76)	2, 3, 4
D01	Develop effective data analytics strategy	3.26 (0.57)	1, 2, 3, 5
D02	Collect and process feedback from people affected by change	3.55 (0.56)	2, 3, 4, 5
D03	Provide sufficient information on the implementation	3.55 (0.61)	1, 2, 3, 4
D04	Reduce variety of different systems for each department	3.10 (0.73)	1, 2, 3, 4, 5
D05	Reduce competitive thinking between departments	2.74 (1.01)	1, 2, 3, 4, 5

on the implementation (D03, $M = 3.55$, $SD = 0.61$) as most important recommendations. Less importance was seen in the reduction of competitive thinking between different departments (D05, $M = 2.74$, $SD = 1.01$). This recommendation shows the highest SD of all recommendations, indicating greater disagreement among participants in rating the importance of this aspect.

In the questionnaire, the participants had the opportunity to name further recommendations for action that they consider important. Several participants mentioned the involvement of employee representatives (e.g. workers' council), risk analyses, and test phases as additional important recommendations. Furthermore, e.g., the use of agile methods, stakeholder analyses, and the assessment of the employees' level of knowledge were mentioned.

When considering the relevance of the recommendations for action for the individual phases of the assumed implementation process model, it can

be noted that no recommendation for action was assigned exclusively to one phase. However, considering external consultants (P12), identifying goals (O03) and a detailed planning of the investment (O05) were seen as relevant specifically in the first two phases. While the planning of training programs for employees (P01) and managers (P04) was considered relevant in the second and third phases, their implementation (P02, P05) was rated as relevant from the third phase onwards. With exception of the category *technology*, several recommendations for action of each category were considered relevant in all phases, e.g., involving affected stakeholders (P06), sufficiently investing in staff (O06), and reducing the variety of different systems for each department (D04). Overall, 18 recommendations were considered relevant in the first phase, 25 in the second phase, 24 in the third phase, and 18 in each of the last two phases out of a total of 27 recommendations assessed.

DISCUSSION AND CONCLUSION

Intelligent support systems seem to be a promising approach to support employees to perform increasingly complex manufacturing planning (cf. Burgert et al., 2022). However, existing implementation strategies for manufacturing support systems rather not focus on intelligent systems. Therefore, this paper contributes a systematic literature review to identify success factors and corresponding recommendations for action, and an empirical study to evaluate them in the context of intelligent support systems for manufacturing planning. As a result, 27 recommendations could be derived and assessed in terms of their importance and allocation to generic implementation phases as a basis for an implementation strategy for intelligent systems to support manufacturing planning.

The results show that all of the recommendations for action evaluated were considered relevant for the implementation of intelligent support systems. It can be noted that many aspects emphasize a strong reference to affected employees, as e.g. by conducting training programs, managing resistance, communicating information on the implementation, and assembling a suitable implementation team. This highlights the importance of involving employees in the implementation. The need for a participatory and human-centered implementation approach already proposed by Mütze-Niewöhner et al. (2022) can therefore be supported by the present results. However, the results indicate that not only employees but all affected stakeholders should be involved. In particular, the managers seem to play an important role with manager commitment seen as one of the most important aspects. Overall, the results suggest that many of the recommendations, especially those related to people, should accompany the entire implementation process.

However, the results of the systematic literature review are subject to limitations, e.g. arising from the subjective perspective of the researchers when deriving and aggregating recommendations. Concerning the empirical study, the validity of results is limited due to the sample size. Also, the additional recommendations mentioned by the participants indicated that further aspects could be certainly relevant. In order to further evaluate the

recommendations for action for the implementation of intelligent support systems for manufacturing planning, the recommendations should be applied in practice and critically reflected upon afterwards.

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