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Implementation of AI Technologies in Manufacturing – Success Factors and Challenges

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ABSTRACT

There is a broad consensus on the potential of smart services for production and the added value their use offers. Industrial artificial intelligence (AI) has several advantages. AI technologies, for example, can strengthen resilience, support work processes, increase product quality and thus improve competitiveness. Many companies have recognised these potentials and are developing AI solutions. There are many successful proof-of-concepts (PoC) and pilot projects, but AI technologies successfully implemented in the real environment are scarce. Successful implementation of smart services based on industrial AI in production operations can be understood as its repetitive use and integration into operational business, which is a prerequisite for exploiting the potentials. Currently, little is known about how to achieve successful implementation. In contrast, there is much evidence that the implementation and operation of AI in manufacturing is associated with extensive challenges and barriers. The factors that positively influence the roll-out of AI technologies in manufacturing, however, are little explored. Therefore, this paper focuses on the identification of success factors and barriers for the implementation and operation of AI solutions in manufacturing. Furthermore, it is analysed whether and how the identified success factors and barriers differ from each other in order to subsequently derive initial recommendations for action. The methodology is based on explorative qualitative research. First, 10 semi-structured interviews were conducted with AI experts from a German Original Equipment Manufacturer (OEM). In an expert workshop, the main findings were validated, and possible solution and support options were discussed. Our findings confirm the results found in the literature and complement them with new insights. Success factors and challenges can be found on the technical, organisational, and human side and relate most often to "data", "development and operational processes" and "stakeholder engagement".

Keywords: Industrial AI, Challenges, Success factors, Technology acceptance

INTRODUCTION

Artificial Intelligence (AI) services are meanwhile well known and are increasingly finding their way into everyday life. The potential of these AI

services is also considered high in the industrial context (Bérubé et al. 2021; Lundborg and Gull 2021). This paper focuses on AI services in manufacturing, also known as Industrial AI. In this paper Industrial AI is defined a "systematic discipline focusing on the development, validation, deployment and maintenance of AI solutions (in their varied forms) for industrial applications with sustainable performance." (Peres et al. 2020). Further we understand Industrial AI services as socio-technical systems as well as tools which assist humans. Industrial AI has several advantages. For example, AI technologies can strengthen resilience, support work processes, increase product quality and thus improve competitiveness. Despite these promising possibilities, few applications using Industrial AI are currently implemented in real environment. Many use cases are developed and tested in laboratory environments and rarely get beyond prototypical status (Lundborg and Gull 2021; Bérubé et al. 2021). Although these prototypes operate well, implementation is associated with many challenges. Based on our experience with industrial business partners, we have come to the assumption that the integration of AI into the real working environment is not as straightforward as it could be. An assumption also made by Bérubé et al. (2021). In addition, there needs to be a broad awareness of the challenges associated with implementing AI services, as these have an impact on successful implementation (Bérubé et al. 2021). In Literature, consensus exists that companies face particular challenges with the implementation of AI services. Commonly mentioned challenges in the literature are related to data (e.g., availability and quality of data, data governance) and the lack of necessary competencies. Further challenges mentioned include a lack of top management support and strategic vision of AI, and uncertainty in regard to the business case (e.g. Bérubé et al. 2021; Goasduff 2019; Peres et al. 2020; IDG Research Serivce 2021; Kinkel et al. 2021). Overall, however, there is little empirical research on factors influencing the successful implementation and operation of Industrial AI services. In particular, little attention is paid to success factors. Aim of this study is to identify success factors for the successful implementation and operation of AI Services in manufacturing, as well as to identify the main challenges associated with this. Therefore, the research question of this study is: *What are the success factors and challenges to the implementation of Industrial AI services in manufacturing?*

METHOD

Since there is little research in this field, the methodology is based on explorative qualitative research. First, 10 AI experts of an OEM were interviewed. Five interview partners were assigned to the IT department and five to the manufacturing department. The interview-guide included questions about daily working routines, AI projects in the company, challenges associated with the development, implementation and operation of AI services in manufacturing, and the associated success factors. Each interview was about 45 minutes. The interviews were conducted virtually via Microsoft Teams. In addition to the interviewee and the interviewer, another person attended the interview to transcribe the conversation. Success factors and challenges were

identified based on inductive categorization (Mayring 2000). Afterwards, the factors were assigned to the categories Human, Technology, and Organisation according to the Human-Technology-Organisation (HTO) concept (Ulich 2013). Identified success factors and challenges were validated in an internal expert workshop. Seven AI experts from different disciplines participated in the online workshop. First, the importance or criticalness of the factors was assessed individually in the workshop via an online questionnaire, then the factors were openly discussed, adapted, and further factors were identified. Furthermore, possible solutions and support options were discussed.

RESULTS

Success Factors and Challenges in Relation With the Implementation of AI Services in Manufacturing

Based on the experience of the total of 17 AI experts, 20 success factors and 31 challenges were identified. We used the HTO-concept to classify these factors. Out of the 20 success factors 8 were assigned to the category Human, 3 to Technology and 9 to Organisation (Table 1). Of the identified challenges, 9 were assigned to the category Human, 14 to Technology and 8 to Organisation (Table 2). In the expert workshop, it became clear that depending on the AI service, challenges and success factors can have a different influence on the development and implementation of AI services. Additionally, an interaction between the factors is to be expected.

Some of the listed factors are described in more detail in the following. According to the interviewees, various stakeholders are involved in the overall AI service engineering process. In their opinion, the support of these stakeholders (e.g., end-users, maintenance, works council, management, Human Resources) is essential for a successful implementation. Further competencies in the field of AI, at least a basic understanding of AI in all related departments would be positive.

When setting up a suitable data set, it is important to have both high-quality data and enough data to train the AI models. The AI experts agree: the more data available for the development of the AI model, the more generalizable the algorithm is and the more stable the AI model runs in productive operation. At the organisational level, rapid development cycles were mentioned as success factor. This refers to short development cycles in which the AI service is put into productive operation as early as possible. Early testing in productive operation improves the product quality and stability of the AI service on the one hand, and on the other hand the added value of the product can be demonstrated at an early stage, thereby gaining support from stakeholders.

The lack of technology acceptance was a frequently mentioned challenge for development, implementation and operation. According to the AI experts, end-users feel threatened by AI technologies and are afraid of losing their jobs. Furthermore, the implementation leads to change and there is often a lack of willingness to embrace something new. The cooperation between

Table 1. Success factors assigned to Human (H), Technology (T) and Organisation (O).

	Success factor
H	Co-determination and participation of end-users in development and implementation
	Confidence in operability of the IT-System
	Managing expectations
	Qualification and competencies in the field of AI among stakeholders
	Support from stakeholders
	Trust in AI
	Usage of demonstrators
	User-centred development
T	Setting up a suitable data set
	Standardization of hardware, software, and AI-modules
	Validation of pre-defined metrics before Roll-Out
O	Added value of the AI service must be clear
	Communication strategy
	Holistic view of digitalisation project
	Data governance
	(Meta)-evaluation of digitalisation projects
	Open corporate culture
	Rapid development loops
	Synchronization of development and approval processes
	Using synergies between projects

IT and manufacturing was also described as challenging. For example, it is perceived as difficult to get access to manufacturing staff.

Undefined roles and responsibilities are a huge challenge coming with the introduction of a new technology into a company. It has not been conclusively clarified which stakeholders are to be included in an AI service engineering process and which responsibilities are to be assigned to which stakeholders. Further roles need to be redefined and responsibilities have to be assigned as well. This makes it particularly difficult to consider and involve all relevant stakeholders.

A pure focus on profitability by the company is perceived as a challenge for technological innovation by the AI experts. Currently, a high front-loading of resources for the development is needed, but this is according to the interviews classified differently by controlling and management.

Possible Solutions and Support Options

In the interviews as well the expert workshop possible solutions and support options were discussed. The discussed opportunities usually address more than one challenge or success factor as well across the Human, Technology and Organisation categories. According to the AI experts, promising opportunities for the successful implementation of AI services in future are interdisciplinary development of AI services, democratization of AI and innovative qualification concepts. These could be AI based on-the-job trainings, the use of digital assistance systems or training through the direct involvement

Table 2. Challenges assigned to Human (H), Technology (T) and Organisation (O).

	Challenging factor
H	Concerns and fear related to AI-Services
	Consider and involve all stakeholders
	Cooperation between IT and manufacturing
	Demotivation due to challenges
	Dissemination of experiential knowledge between AI-Developers
	False expectations of the end-user in the AI service
	Lack of competencies among stakeholders
	Lack of management-commitment
	Lack of technology acceptance among stakeholders
T	Complexity of AI-Services
	Context sensitivity of AI
	Data privacy
	Development in laboratory environments
	Development of a suitable architecture
	Identification of applicable algorithms
	Integration into existing IT-Infrastructure
	Lack of data quality and availability
	Lack of standardization
	Non-transparency of AI
	Onsite IT-integration
	Response time of AI models
	Security concerns related to cloud solutions
	Unbiased AI
O	Building a business-case for AI services
	Company focusses purely on profitability
	Ensure productive operation and support
	Established software engineering processes are insufficiently designed for AI
	Time-consuming administrative tasks and processes
	Uncertainty about development and approval processes
	Undefined roles and responsibilities
	Value of data is not recognized

of end users in development projects. Within a company, cooperation between development projects and a professional knowledge management for AI development should be supported. Further descriptions of best-practice use cases and guidelines for AI service development and implementation processes can be helpful for a successful implementation according to the AI experts. Suggested technical solutions include intensifying platform ecosystems for industrial AI services, promoting standardization and introducing a Machine Learning Operations (MLOps) approach model.

CONCLUSION

Using an explorative qualitative research design this study analysed success factors and challenges related to the implementation of Industrial AI services. Some challenges known from literature were also mentioned by our

interview partners, such as data related problems and the lack of competencies. In addition, other challenges were identified. For example, difficulties in cooperation between IT and manufacturing, the development in laboratory environments and undefined roles and responsibilities. Moreover, our study explores success factors of the implementation of Industrial AI services. Success factors mentioned by our interview partners could mainly assigned to the human and organisational side.

It is important for researchers as well as companies to understand the positive and negative factors that influence the introduction of AI services. Only if these are known it is possible to create a successful implementation process. The present results are complementary to the little existing empirical knowledge in this research area. Nevertheless, further research is needed to gain a better understanding of the influencing factors, e.g., the dependency and relative importance of the factors. Furthermore, some factors are described as success factors as well as a challenge by the interviewees. Further research is needed to analyse whether these factors are independent or represent poles of one dimension. It must also be considered that the sample of the present study is limited to AI experts. All stakeholders involved in the process of implementing AI services, especially end-users, should be interviewed in further studies to gain a comprehensive understanding. Generally, there is little experience with the successful implementation of Industrial AI services. Ethnographic research methods could provide further important insights in future.

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