Are We There Yet?—Looking at the Progress of Digitalization in Maintenance Based on Interview Studies Within the Swedish Maintenance Ecosystem

Mirka Kans

Abstract Industry 4.0 promises huge effects on industrial performance, once critical equipment is equipped with sensors and interconnected, and big data sets and digital twins are established that allows for advanced data analytics using machine learning, cognitive computing, and information visualization techniques. Maintenance is an area of industrial activities that would greatly benefit from the implementation of Industry 4.0. But how far has the digital transformation progress come? In 2018, an interview study was performed with 14 representatives within the maintenance ecosystem during the Nordic maintenance fare held in Gothenburg. A similar study was performed at the fare held in 2022, in which 22 actors representing system providers, computerized maintenance management suppliers, researchers, and educators participated. The aim of the studies was to get a broad view on maintenance in the digital era, covering topics like enabling technologies, challenges as well as opportunities. This paper reports on the similarities and differences in results from the two interview studies and draws conclusions on the progress and directions of the digitalization in maintenance. The findings suggest that the progress is rather slow. Data management and decision-making capabilities forms the basis for digitalization of maintenance. The focus on sensor technology has somewhat been reduced, while the prediction was that it would have increased. Instead, the ability to communicate and share information is stressed. Advanced analytical capabilities are foreseen to have a breakthrough in five years' time, as well as technologies for data gathering and communication. The challenges are mainly the same, i.e., related to competence, leadership, and strategy. This suggests that, to enable the digital transformation, we should focus on the formulation of appropriate business cases and initiation of pilot studies, supporting the implementation process and involving all people in the change, and securing the competence and skills by training, education, and recruitment of young people to maintenance positions.

M. Kans (✉)
Chalmers University of Technology, Vera Sandbergs Allé 8 SE-412 96, Göteborg, Sweden
e-mail: mirka.kans@chalmers.se

U. Kumar et al. (eds.), *International Congress and Workshop on Industrial AI and eMaintenance 2023*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-3-031-39619-9_41

Keywords Maintenance digital transformation · Digitalization in maintenance · Industry 4.0 · Interview study · Comparative study · Challenges and opportunities · Swedish maintenance ecosystem

1 Introduction

The digitalization of maintenance started over 40 years ago [1], and the term condition-based maintenance (CBM) have been used for about the same amount of time [2]. CBM is a data-driven and knowledge-based maintenance strategy that is enabled by emerging technologies. Industry 4.0 has been a hot topic for practitioners as well as researchers the past decade and is seen as an industrial revolution characterized by smart systems and Internet-based solutions that allows for creating effective, integrated, and flexible production and information flows [3–5]. Maintenance 4.0 can be viewed as a subset of Industry 4.0 allowing for efficient and automatic management of maintenance through automatic data collection, analysis, visualization, and decision making [6]. Emerging technologies of Industry 4.0 comprise information and communication technologies as well as electronics and process control technology [7], which provides the organization with digital capabilities of (1) Connecting and storing, (2) Understanding and acting, and (3) Predicting and self-optimizing [8].

Connecting and storing are the basic capabilities of Industry 4.0 enabled by Internet of things (IoT), i.e., objects fitted with sensors and processors that communicate and interact with each other [9, 10]. IoT enables the collection of large amounts of data, which are referred to as Big Data (BD). Mobile computing and Cloud Computing (CC) serves as the backbone for data collection and storing [6]. The term Cyber-Physical System (CPS) is often used to describe the total system that is connected as a network but shares the physical world, such as hardware, with a variety of communication systems that interact in the physical world [11]. Data carrying devices such as Radio Frequency IDentification (RFID) makes it possible to trace products and components through the manufacturing process [12].

Understanding and acting capabilities are those that give the organization the ability to monitor and control different processes. The enormous amount of data that is created with digitalized systems for connecting and storing require processing capability such as Machine Learning (ML) algorithms or other AI applications [6, 10, 12]. The purpose of AI is to mimic the brain's ability to solve problems, plan, and draw conclusions, plan, and solve problems [13]. Machine learning is the use of mathematical or statistical methods for pattern recognition in big data sets [14–16] and gives opportunities for improved failure diagnostics and maintenance planning [17]. For optimized decision-making, the information should be presented in a form that is recognized and understood by a human. Visualization reinforces human cognition by presenting large amount of qualitative or quantitative data [18].

Predicting and self-optimizing capabilities are advanced analytical capabilities that enables the organization to work predictively and prescriptible. This is enabled by AI technologies such as Deep Learning (DL), which is an advanced form of machine

learning using neural network methods. Self-optimizing machines could be in the form of automated planning and scheduling or self-adapting and self-maintaining machinery, or Intelligent Robotics [12, 19].

Emerging technologies could also support the practical execution of maintenance. Augmented reality (AR) and virtual reality (VR) enables the users, such as maintenance technicians, to interact with a virtual environment for training purposes or for supporting the execution of complex tasks [18, 19].

The main purpose of this paper is to understand the opportunities as well as challenges faced in maintenance with respect to emerging Industry 4.0 technologies, and how to support the digital transformation in the best way. For reaching the purpose, two interview surveys were conducted in 2018 and 2022 aiming at creating a broad view on maintenance in the digital era from various Swedish actors, such as technology providers, computerized maintenance management suppliers, consultants, researchers, and educators. The paper disposition is as follows: Sect. 2 presents the study setup and Sect. 3 the main results from the two studies, ending with a comparative and forward looking discussion based on the study results. General conclusions as well as areas of future research are given in Sect. 4.

2 Method

In 2018, an interview study was performed with representatives within the maintenance ecosystem during the major bi-annual Nordic maintenance fare held in Gothenburg. The fare is the largest maintenance related event in Northern Europe consisting of over 300 exhibitors and 11 000 visitors, and attracts companies, practitioners as well as researchers [20]. The aim of the study was to get a broad view on maintenance in the digital era, covering topics like enabling technologies, challenges as well as opportunities. Study participants were 14 actors representing system providers, computerized maintenance management suppliers, researchers, and educators. A similar study was performed at the Nordic maintenance fare held in 2022, in which 22 actors representing system providers, computerized maintenance management suppliers, researchers, and educators participated. The study participants are summarized in Table 1. Note: in the table the total number (41) is higher than the number of participants (36) as some participants represent more than one actor type.

The interviews lasted about 30 min each were based on four predetermined and open-ended questions:

1. Which technology do you view as the most important today for developing maintenance, and within which area (planning, preparation, execution, follow-up, improvement of maintenance)?
2. Which technology has made its breakthrough in five years' time, and which area has developed most?
3. Which are the biggest digital challenges in maintenance?
4. How can the digital development best be facilitated?

Table 1 Study participants

Actor type	2018	2022	Total
Maintenance consulting services	3	6	9
Technology/IT consulting services	1	4	5
Supplier of IT solutions	4	6	10
Supplier of technology solutions	0	4	4
Supplier of products	2	0	2
Trade organization	1	0	1
Education	3	2	5
Research	2	3	5

In the 2022 interview study, the following question was added:

5. Imagine the scenario that we achieved full Industry 4.0. What new challenges will we encounter?

The participants were free to give other comments upon the subject as well.

3 Results

The results are presented in the same order as the questions. 3.1 comprises results from questions one and two, 3.2 results from question three, and 3.3 results from question four. Question five, which was included in the 2022 study, is used as basis for the comparative discussion in 3.4.

3.1 Enabling Technologies in Maintenance

3.1.1 Enabling Technologies of Today (2018 and 2022 Respectively)

Digitalization affects all areas of maintenance management, according to the participants in 2018. Especially planning is enabled by digital solutions, but also follow-up and improvement of maintenance. Many participants viewed digitalization as the way to reach condition-based and predictive maintenance but also a reality where sensor data were hard to utilize efficiently for the planning or improvement of maintenance. Technologies that enable condition-based maintenance (CBM) was the most common enabling technology mentioned in 2018. A wide set of technologies were mentioned, of which the following three were most frequent:

- Sensor technology
- Machine learning
- Visualization

These technologies support a CBM approach: The ability to collect real time data from the production and machines is the basis for advanced analysis of the data. Advanced planning engines, using machine learning or other artificial intelligence solutions for analyzing the large data sets retrieved from production, will enable the transformation of maintenance planning from calendar based to predictive and condition-based maintenance, according to the study participants. The ability to analyze large sets of data and present the results in an understandable way for internal as well as external actors is enabled by visualization. In summary, all three types of capabilities were emphasized in the 2018 study.

The participants of the 2022 study emphasized the Computerized Maintenance Management System (CMMS) as being the backbone of effective maintenance planning. Having a solid digital basis in the form of a CMMS, which is integrated with other systems, is seen as the main enabler. The largest impact of digitalization is seen in the areas of follow-up and improvement, though. The three most frequently mentioned technologies in 2022 were:

- CMMS
- Mobile devices
- Internet of Things (IoT)

The capabilities to connect and store information are supported by these technologies. Communication technology and data processing were also mentioned by several participants. While some respondents argued for building a sound digital base is most important, others viewed artificial intelligence (AI) and IoT as important complements to the CMMS mainly for building understanding and acting capabilities. Some participant mentioned the ability to predict, or to be able to move from breakdown to preventive maintenance. Many saw all Internet 4.0 technologies as potentially important, and one respondent explained: "Perhaps the important thing is not which technology, but to start using one of them."

3.1.2 Enabling Technologies of Tomorrow

In 2018, the study participants depicted a near future where Industry 4.0 has become a reality in maintenance. The maintenance strategy of tomorrow is highly condition-based and predictive. IoT supports in collecting and managing sensor data while ML, deep learning, visualization, and digital twins are used for big data analytics. Two areas were pointed out as being mostly developed by digitalization: execution and follow-up. Mobile devises and Augmented Reality (AR) support the maintenance technicians in their daily work. New or complex tasks can be monitored and guided from a remote monitoring central. Planning and follow-up of operations is made remotely. Everything is connected creating vulnerability in the system. Thus, safety is a key concept.

In 2022, planning and improvement were the areas with largest impact of digitalization in the future, according to the participants. This is highly reflected in the enabling technologies that were most frequently mentioned: technologies for big data

analytics, such as ML and AI, and for communication, such as Machine-to-machine communication and IoT. One participant mentioned the connection of people as important, as well. Although not in focus as areas that have developed most, we find that the participants recognize AR and mobile solutions as important digital support for the maintenance technicians in the future. The increased use of AR and VR solutions in five years' time was not realistic, one participant claimed: there are several issues that must be solved for technologies that are to be worn by people, but maybe these issues are solved in ten years' time.

3.2 Digital Challenges in Maintenance

In the 2018 study, the main challenges for efficient digitalization were related to the organization and people, such as inability to connect technology investments to business needs, unwillingness to change, and lack of competence. Amongst issues connected with investment decisions, it is hard to identify business cases that will utilize digitalization is an efficient manner, hard to translate digital opportunities to business opportunities, and to know where to start the digital transformation The inability to understand how to make business out of digitalization relates to strategy and leadership. Unwillingness to change and lack of competence are mainly related to people and culture. Low level of formal as well as real competence affects the possibilities to implement digital solutions. The high age of personnel was also mentioned. Rigid cultures and manual maintenance management were seen as problematic as well. It was noted that many maintenance departments did not have a CMMS implemented, which makes the gap and the journey towards digitalization huge. Technology fear and unwillingness to change adds to the challenge. Issues with low integration of existing technologies, cybersecurity, and technologies with low user friendliness are also hindering the implementation.

Organizational aspects connected with leadership and people were seen as the biggest challenges in 2022. Main challenge in leadership is being able to support the improvement and change work. The unwillingness and fear of change on all levels from the end user to the management. was seen as a main hinder by several participants. This is a leadership issue that often is combined with unwillingness to invest or the inability to understand the importance of digitalization, i.e., a strategic aspect. Without the top management support, there will be no room for investments and, thus, no incentives for change. It is also connected with the departmental culture that creates barriers and hinders information sharing between the maintenance department and other departments. The absolute biggest challenge is lack of all kinds of competence, though. Digitalization requires new kind of competences for handling technology and analyzing data, but basic maintenance related competence is highly missing as well. Many respondents mentioned the generation shift, and how hard it is to attract young people. Amongst the challenges connected with technology were system integration, cybersecurity, and lack of user friendliness. One participant mentioned poor collaboration with suppliers.

Table 2 summarizes the challenges identified in 2018 and 2022. We can note both similarities and differences between the answers. For the strategic aspects, the main theme is the inability to align business and maintenance strategy with suitable technology. This was seen as a managerial problem as well in 2018, and the managerial problems are mainly appearing before an implementation has taken place. In 2022, the leadership aspects are emphasizing challenges in the improvement and change processes. Something that is recurrent in 2018 and 2022 is the unwillingness to change; it is mentioned on organizational, leadership, and people level. The culture aspect differs between the studies: while culture is seen as a hinder for digitalization in 2018, the hinders connected with culture in 2022 regards internal cooperation and collaboration. The challenges related with people are much the same; there is a lack of competence and lack of personnel. Unwillingness to change and technology fear is also mentioned both in 2018 and 2022. Security aspects are mentioned both in 2018 and 2022, as well as the lack of integration of systems and low user friendliness.

3.3 Facilitating the Digital Transformation

In the study conducted 2018, the participants saw companies, suppliers, educators as well as researchers as facilitators. Companies should in firsthand approach the challenges that were present, for instance by improving the culture and leadership, and to start the process somewhere, such as feeding data into existing systems for achieving better decision making capabilities. Letting go and dare to try is one way to learn. Another way is to recruit new personnel. Young people like to be challenged and work with problem solving. A key is therefore to promote maintenance as a function where problem solving skills are needed. The suppliers could become better in describing available solutions and develop solutions that are compatible with existing systems. The suppliers and trade organizations were seen as important actors for aligning digitalization efforts in maintenance with business objectives; they could utilize their expert knowledge to help companies in finding good business cases and for describing the positive impacts that are achieved with effective and digitalized maintenance strategies. Trade organizations and standardization bodies have an important role in developing new standards both within the maintenance area and for the technologies. Education was mentioned by several participants. Educators have an important role in attracting young people to maintenance related education on all levels. One participant suggested standardizing the competence requirements according to the European qualifications for maintenance personnel. All actors should work together to facilitate the digitalization. For reaching this, sharing data, experiences and knowledge is essential. One example of shared data could be sensor data generated by a school or university that is open for everyone to download and analyze.

In 2022, two main themes are seen: how to prepare the organization for change and how to support the successful implementation of digital technologies. Both are in firsthand a managerial problem addressing leadership, culture, and people. Amongst

Table 2 Challenges identified in 2018 and 2022

Category	2018	2022
Strategy	(1) Unclear what technology to invest in as the development is so fast (2) Hard to find the business cases (3) Inability to connect technology with current business processes (4) Low use of available technologies	(1) Poor willingness to invest (2) Poor connection between technology and utilisation (3) Poor understanding of the importance of maintenance (4) To change from preventive to predictive maintenance strategies
Leadership	(1) Unwillingness to change (2) The value of maintenance is not understood (3) Hard to convince decision makers that a system is useful (the maintenance representative understands, but has no authority to bring it further to the decision makers)	(1) Poor leadership (2) Poor adaptability (3) Not working with continuous improvements (4) Poor support and management for improvements and change in the organisation (5) Top-down management of change (6) Not enough benchmarking, learning from each other (7) Older managers' unwillingness to digitize (8) Not understanding and carrying out the change completely
Culture	(1) Culture and people are interconnected–an openness to technology development is lacking (2) Companies do not dare to start using digitalisation (3) Hard to get companies to use the technology—go from paper and pen to Excel! (4) Technology is not seen as an enabler (5) To overcome technology fear	(1) A departmental culture that creates barriers and missing information (2) Culture of firefighting (3) Unwillingness to share data
People	(1) Low level of competence (2) Lack of competence (such as technology competence) (3) Lack of social skills, cooperation problems (4) New types of jobs—from operations to control (5) Unwillingness to change (6) Getting employees to change their mind set (7) Technology fear (is seen as something that will replace personnel instead of supporting them) (8) Aging personnel	(1) Poor digital knowledge and competence, e.g., understanding of computer/machine communication (2) Lack of competence in all areas (3) Technology fear (4) Being afraid of change, low trust (5) Hard and difficult with new things, to get humans on the track–to keep pace with technology (6) Mindset of people, e.g., rely on technology to take care of everything (7) Acceptance and adaptability of technicians for new technology. Sometime, young managers might be unwilling to digitalize as well (8) Lack of personnel (9) Change-of-generation

(continued)

Table 2 (continued)

Category	2018	2022
Governance	(1) Rigid mind-set regarding data security (2) Poor support systems	(1) Cybersecurity
Technology	(1) Intuitiveness of systems (2) New innovation such as Windows 95 is needed (3) A complete environment is lacking	(1) System integration (2) Lack of user friendliness (3) Poor collaboration with suppliers

suggestions for managing change is to make the work meaningful for the personnel, trust in people, use ambassadors of digitalization, and describe digitalization in a pedagogic way. As one of the participants stated: "Administrative tasks are mainly forced on us and we should get something back from it." Adding new tasks to the personnel without giving them incentives is a hinder, and not an enabler. Having the right competence is a main facilitator for the successful implementation. One participant explained that all personnel should have a basic understanding of e.g., robotics and be able to use smart phones for easy data retrieval. This is achieved by education and competence development e.g., through dynamic learning platforms, or by acquiring competence e.g., by attracting young people and female. The latter has positive impact on the culture as well. Other means to achieve successful implementation are management involvement, communication and information sharing, cooperation and networking, and by applying a systems perspective. Good implementation practices will create trust, one participant mentioned. Other ways to facilitate digitalization is by developing cheaper technology solution and increasing the user friendliness. Reliable internet connection was mentioned by one participant, as this is the foundation of the Industry 4.0 concept. The main drivers of change are the companies and the suppliers, according to the study participants. Education was the most frequently mentioned facilitator, though, which implies that educators play an important role as well.

3.4 Where Are We Headed?

At a first glance, it might seem like the digital development in maintenance has stalled or even reversed. Digital capabilities of *connecting and storing*, *understanding and acting*, and *predicting and self-optimizing* creates the backbone for predictive and prescriptive maintenance strategies. In 2018, the current enabling technologies were closely connected with these capabilities supporting CBM and predictive maintenance, and this was also depicted as the near future. In 2022, however, the connecting and storing capabilities were seen as enablers of today, while understanding and acting, and predicting and self-optimizing based on big data analytics were seen as enablers of tomorrow. However, this might be interpreted as a change of mindset from pure technology focus to a focus on utility in first hand, where the participant

answers of 2022 are closer to reality than the answers of 2018, that might describe "wants and hopes" of the participants rather than the reality. It might also reflect a more sober view on how to approach the implementation of emerging technologies. Without a solid base, which is reflected in collecting and storing capabilities, it is hard to achieve good results of advanced analytics, represented by understanding and acting, and predicting and self-optimizing capabilities. The true utilization of emerging technologies in Sweden is, most likely, for connecting and storing, and understanding and acting, while only few organizations have reached predicting and self-optimizing digital capabilities.

Looking at the challenges we see that, although many hinders stays the same, there is a noticeable difference in challenges connected with leadership and culture aspects. In 2018, the managers struggled with getting improvement projects accepted due to the inability to express the benefits from the project. In 2022, however, the managers struggle with carrying out implementation projects. It seems like companies have started to implement emerging technologies! How to prepare the organization for change and how to support the successful implementation of digital technologies were also the main facilitating factors in the 2022 study.

In a future where Industry 4.0 is fully implemented, the main challenges of securing maintenance and digital competence remains, according to the 2022 participants. Recruitment will be important in the future, just as it is today. One participant foresees a shift in maintenance tasks and the challenge in finding new tasks for the maintenance technicians. The most frequent and spontaneous answer was "Industry 5.0". It is obvious that the role of people will increase rather than decrease. Moreover, participants believe that the technology related challenges will increase. For instance, the need to maintain all the emerging technologies is recognized. Cybersecurity will also be a challenge. In addition, working with continuous improvement was seen as a challenge of the future. The benefits of maintenance digitalization seem to be understood in the future. Instead, the challenge is to explain the impacts on sustainability. As one participant said: "To make it environmentally friendly, not only optimize machines to reduce energy and costs."

4 Conclusions

While it is positive that companies seem to run digitalization projects, we should be aware of how the implementation is carried out. In order to address the challenges, we need to promote cooperation between departments, and give space and time for collaborative learning and knowledge creation during and after the improvement projects. One way is to find joint business cases, i.e., projects that benefits more than one department.

The main challenges were seen in the areas of people, culture, and leadership. The successful implementation is, thus, clearly connected with the core organizational capabilities. Change management is the process of understanding why changes have to be made, and how, and has impact on individual, organizational as well as cultural

level [21]. The benefits in digitalization have to be understood and communicated. Technology fear could be addressed by pointing out the positive effects for the organization as well as for the individual worker. Formulating IT governance strategies and digitalization strategies supports the change [22]. The intellectual capital of personnel represents up to 80% of the total resources in the modern organization [23]. Preparing the personnel for the change by competence development and active participation in the implementation already in an early stage are therefore ways to increase the possibilities of succeeding. For the management, it is important to gain better understanding and suitable methods for the implementation process [24].

Being first in adopting emerging technologies might be hard. However, it is also recognized that the ones that dares to move fast in a business transformation are the ones that can gain competitive advantages. Developing a clear business case and having the financial possibility could definitely pay off. In order to do so, the view of maintenance has to change; from a necessary and unwanted cost to a business opportunity [25]. Thus, there exists a huge pedagogic task in describing the benefits of digitalization in maintenance, which involves both internal and external actors. Maintenance managers have to better explain the positive effects that could be gained from improvements and innovations, suppliers must explain quantitative as well as qualitative returns on investments in their technology solutions, and trade organizations and researchers have to develop pedagogic material and case studies that highlights the benefits of digitalization in maintenance.

This study is of preliminary and inductive nature where the results have to be understood in the context in which they were gained. Therefore, limited possibilities exist to draw general conclusions. The comparative nature gives some interesting indications, though, that could be followed up in a larger longitudinal survey study.

Acknowledgements The author would like to thank all participants in the study for sharing valuable knowledge, insights, and thoughts.

References

1. Kans M, Campos J, Salonen A, Bengtsson M (2017) The thinking industry: an approach for gaining highest advantage of digitalisation within maintenance. J Maint Eng 2:147–158
2. Bengtsson M (2008) Supporting implementation of condition based maintenance: highlighting the interplay between technical constituents and human and organizational factors. Int J Technol Hum Interact 4(1):49–75
3. Weyer S, Schmitt M, Ohmer M, Gorecky D (2015) Towards industry 4.0-standardization as the crucial challenge for highly modular, multi-vendor production systems. IFAC PapersOnLine 48:579–584
4. Sanders A, Elangeswaran C, Wulfsberg J (2016) Industry 4.0 functions as enablers for lean manufacturing. J Indust Eng Manag 9(3):811–833
5. Lasi H, Fettke P, Kemper H-G, Feld T, Hoffmann M (2014) Industry 4.0. Bus Inf Syst Eng 6:239–242
6. Kans M, Galar D, Thaduri A (2016) Maintenance 4.0 in railway transportation industry. In: Proceedings of the 10th world congress on engineering asset management, pp 317–331

7. Lu Y (2017) Industry 4.0: a survey on technologies, applications and open research issues. J Ind Inf Integr 6:1–10
8. Huber R, Oberländer AM, Faisst U (2022) Disentangling capabilities for industry 4.0-an information systems capability perspective. Inf Syst Front. https://doi.org/10.1007/s10796-022-10260-x
9. Hofmann E, Rusch M (2017) Industry 4.0 and the current status as well as future prospects on logistics. Comput Ind 89(1):23–34
10. Marcucci G, Antomarioni S, Ciarapica FE, Bevilacqua M (2022) The impact of operations and IT-related Industry 4.0 key technologies on organizational resilience. Prod Plan Control 33(15):1417–1431
11. Mosterman P, Zander J (2016) Industry 4.0 as a cyber-physical system study. Softw Syst Model 15(1):17–29
12. Alcácer V, Cruz-Machado V (2019) Scanning the industry 4.0: a literature review on technologies for manufacturing systems. Eng Sci Technol Int J 22(3):899–919
13. Tecuci G (2012) Artificial intelligence. WIREs Compute Stat 4:168–180
14. Moret-Bonillo V (2018) Emerging technologies in artificial intelligence: quantum rule-based systems. Prog Artif Intell 7(2):155–166
15. O'Leary DE (2013) Artificial intelligence and big data. IEEE Intell Syst 28(2):96–99
16. Juuso EK (2018) Smart adaptive big data analysis with advanced deep learning. Open Eng 8(1):403–416
17. Pye A (2014) The internet of things connecting the unconnected. Eng Technol 9(11):64–70
18. Penna R, Amaral M, Espíndola D, Botelho S, Duarte N, Pereira CE, Zuccolotto M, Morosini Frazzon E (2014) Visualization tool for cyber-physical maintenance systems. In: Proceedings of 12th IEEE international conference on industrial informatics (INDIN), pp 566–571
19. Rikalovic A, Suzic N, Bajic B, Piuri V (2022) Industry 4.0 implementation challenges and opportunities: a technological perspective. IEEE Syst J Syst J 16(2):2797–2810
20. Underhållsmässan (2023). https://en.underhall.se/, visited 2023–03–01
21. May G, Stahl B (2017) The significance of organizational change management for sustainable competitiveness in manufacturing: exploring the firm archetypes. Int J Prod Res 55(15):4450–4465
22. Kans M (2018) IT governance from the operational perspective: a study of IT governance strategies applied within maintenance management. Int J Serv Technol Manage 24:263–288
23. Jacobsen DI, Thorsvik J (2008) Hur moderna organisationer fungerar. Lund, Studentlitteratur AB
24. Campos J, Kans M, Salonen A (2021) A project management methodology to achieve successful digitalization in maintenance organizations. Int J COMADEM 24(1):3–9
25. Kans M, Ingwald A (2016) A framework for business model development for reaching service management 4.0. J Maint Eng 1:398–407