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Hindering Factors in Smart Maintenance Implementation

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Abstract. In today's industrial environment, innovations and advancements in technology are extremely fast. This development has led to a Fourth Industrial Revolution where industrial companies strive to achieve highly digitalized and resilient production systems. To realize such production systems, the role of maintenance is critical. Industrial companies are anticipated to transform their maintenance organizations towards Smart Maintenance, but they need evidence-based guidance in pursuing such an implementation. Thus, the purpose of this paper is to support industry practitioners in their Smart Maintenance implementation. By means of an empirical case study within energy production, this paper identifies and describes hindering factors that impede the implementation of Smart Maintenance, as well as provides recommendations for overcoming the hindering factors. The recommendations can be used by industry practitioners to increase the likelihood of success in their Smart Maintenance implementation, thereby helping industrial companies in their development of sustainable and resilient production systems.

Keywords. Smart Maintenance, energy production, case study, strategy, implementation

1. Introduction

Innovations and advancements in technology create new opportunities for designing and running production systems. The phenomenon of a digitalized industry is emerging, and terms such as "Industry 4.0", "digitalized manufacturing", "Smart Manufacturing", and "Fourth Industrial Revolution", indicates that this is on the agenda for many industrial companies [1,2]. Industrial companies need to respond to this changing environment by ensuring that strategies, organizational structures, and management support this technological shift [3,4]. Especially, it is clear that maintenance, "*procedures that make production systems work*" [5], will play a critical role. Thus, the maintenance organization must develop to fit with the emerging digitalized industry [6,7].

Smart Maintenance is a concept that describes how maintenance organizations work in digitalized environments. It is characterized by making maintenance decisions based on data (data-driven decision-making), continuously developing and renewing the competence of the maintenance employees (human capital resource), and integrating the maintenance function with other functions within the plant (internal integration) as well as external parties (external integration) [6]. Consequently, industrial companies need to develop their strategies accordingly to succeed with such implementation. However, the

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maintenance research field is mainly characterized by a focus on technology, with less research devoted to guiding industrial companies in organizational change [8]. Most research regarding organizational change focuses on the preparation of the change, missing attention to the execution of the change [9], and there are not yet many implementation cases of Smart Maintenance reported in research.

In an ongoing research project, we aimed to study the implementation of Smart Maintenance within an energy production company. However, early in the project, we faced hindering factors that impeded the implementation process. In this paper, we identify and describe these hindering factors, aiming to disseminate lessons learned to industry practitioners; so as to support them in their Smart Maintenance implementation.

2. Theoretical background

The industry is undergoing a technological shift. Technologies such as cyber-physical systems (CPS), the Internet of things (IoT), cloud computing, and 3D printing [10,11] are changing the industrial environment, including the production systems, value chains, and business models [12]. This, in turn, will affect strategy development and organizational structures [3,4]. This paper focuses on the maintenance function, intuitively defined as *"procedures that make production systems work"* [5]. Maintenance research has accelerated in recent years, where concepts such as "predictive maintenance", "maintenance 4.0", "e-maintenance", and "Smart Maintenance" have been developed in response to the emerging digitalized environment. In summary, maintenance in digitalised manufacturing includes technologies for condition monitoring of equipment, remote supervision for repair and troubleshooting, root cause analysis, calculation of remaining useful life, and failure prediction [13,14,15,16]. Especially predictive maintenance has received a high level of interest. By detecting anomalies in data, artificial intelligence (AI) and machine learning (ML) can be used to predict equipment breakdowns [17,18]. These technologies are anticipated to increase maintenance performance and ensure highly reliable production systems, as well as increase financial performance at a company level.

The concepts describing maintenance in digitalised manufacturing share an emphasis on technologies whose use will require a strategic development of the maintenance organization [6,7]. "Smart Maintenance", defined by Bokrantz et al. [6] as "*an organizational design for managing the maintenance of manufacturing plants in environments with pervasive digital technologies*", brings clarity to the requirements of such a development. Smart Maintenance consists of four core dimensions: (1) data-driven decision-making (the extent to which maintenance decisions are based on data); (2) human capital resource (the knowledge, skills, and abilities of the maintenance employees, including e.g. traditional hands-on maintenance skills, specific skills such as data analytics, and generic skills such as communication); (3) internal integration (the maintenance function is part of a unified whole within the plant, meaning that the maintenance function and its processes are well-synchronized with the rest of the plant organization); and (4) external integration (the maintenance function is part of a unified whole outside the plant, meaning that it works closely together with external parties) [6].

In both research and practice, conventional maintenance strategies focus more on the technical aspects of equipment (e.g. choice of maintenance policy) rather than the organizational development of the maintenance function [8,19]. Therefore, Smart Maintenance provides added value to maintenance strategy development through a novel and holistic perspective that also include organizational aspects [6,20,21]. To support the development of Smart Maintenance strategies, Lundgren et al. [19] proposed a structured work process. The process is cyclical and comprises six steps: (1) benchmarking of the maintenance organization using Smart Maintenance assessment (SMASh) in [22]: a measurement instrument that identifies the current level of Smart Maintenance in the organization; (2) setting clear goals that are aligned with the overall company goals as well as individual goals of the maintenance employees; (3) setting strategic priorities to ensure that activities are executed in the correct sequence to support the interplay among the four dimensions; (4) planning key activities, preferably visualized in a roadmap; (5) elevate the implementation by putting planned activities into action; and (6) following up the activities and the associated effects. In addition, this process supports several essential aspects of organizational development, such as engagement among employees [23], strategic alignment [24], as well as dynamics of the strategy to evolve with the organization [25]. Further, leadership and management commitment are central parts of organizational change [9,26,27].

3. Methodology

We conducted a single case study within an energy production company to study Smart Maintenance implementation in a real-life context [28,29]. In an ongoing research project about Smart Maintenance in energy production, we aimed to deploy the strategy development process for Smart Maintenance implementation suggested by Lundgren et al. [19]. However, a complete strategy for Smart Maintenance implementation was not reached as we faced hindering factors that impeded the process. This allowed us to identify and describe potential hindering factors as well as provide recommendations for overcoming them, with the aim of supporting industrial companies in their Smart Maintenance implementation.

3.1. Data collection

Semi-structured interviews were used to collect data about potential hindering factors. Four respondents were selected based on three criteria: (1) being involved in the research project, (2) holding experience in strategy development, and (3) possessing a managerial role with direct influence on daily operations. The interviews were conducted by one researcher online and lasted for approximately 45 minutes. The interview focused on uncovering the experiences from working in the research project; implementation processes in general; and Smart Maintenance implementation in particular. Digital notes were taken during the interviews, which were used for analysis.

3.2. Data analysis

An inductive approach was used for data analysis. Specifically, open coding was used to create a data structure, inspired by Gioia et al. [30], which transparently shows how statements from the interviews (1st order codes) emerged into hindering factors (2nd order codes). The notes from the interviews were imported to Nvivo, and subsequently coded into 1st order codes [31]. Each 1st order code was formulated to reflect the substantive meaning of the statement made by the interviewees. Thereafter, we constructed 2nd order codes that reflected the emergent patterns of the 1st order codes. The 2nd order codes were identified as hindering factors, each supported by at least three 1st order codes. Next, we developed a set of recommendations based on ideas from the interviewees, researchers' experiences, and literature. Finally, concrete activities were listed for each of the hindering factors (presented in the recommendation chapter).

4. Results

A summary of how the 1st order codes emerged to 2nd order codes (i.e., hindering factors) is summarized in Figure 1.

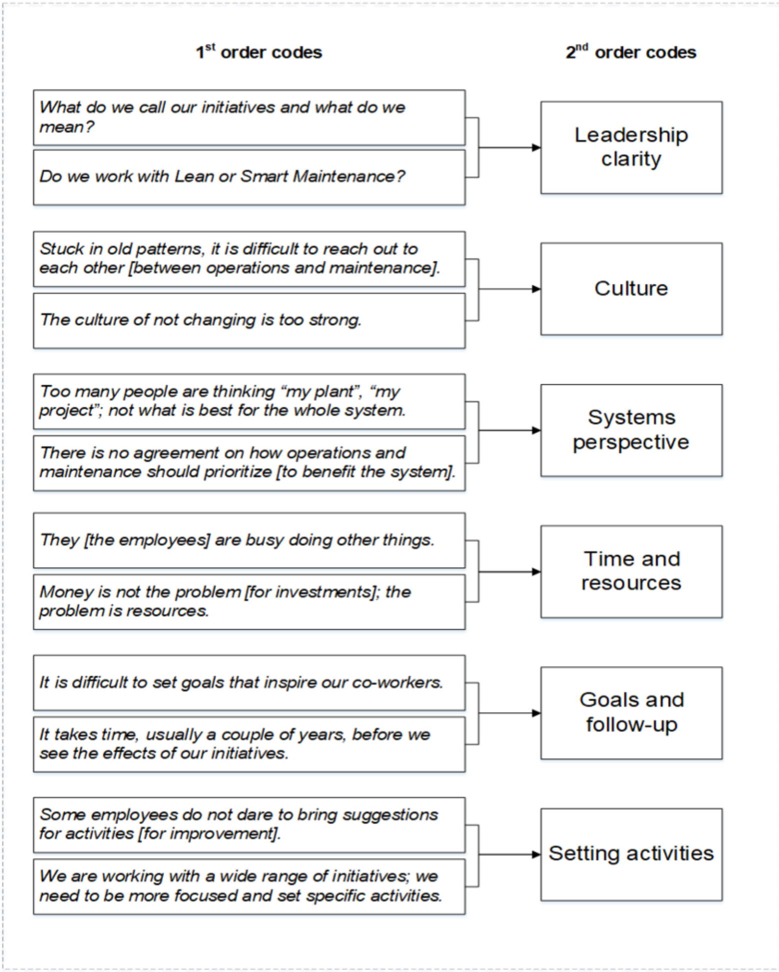

Figure 1. Visualization of data structures; how statements from the interviews emerged to hindering factors.

Figure 1 shows the identified hindering factors along with examples of statements from the interviews. Six hindering factors were identified: Leadership clarity; Culture; Systems perspective; Time and resources; Goals and follow-up; Setting activities. The conceptual content of each hindering factor is described below.

Leadership clarity: The case company has several ongoing initiatives, e.g., Lean, Smart Maintenance, and Data Analytics, which results in a lack of leadership clarity concerning the organization's focus. This makes it difficult to achieve commitment among the employees as they perceive it unclear as to how the organization should work.

Culture: History and traditions within the organization influence the collaboration between functions. Primarily, a dissent between operations and maintenance has been present for a long time, making collaboration difficult. In addition, a strong culture of resistance to change permeates the entire organization. Thus, old cultural patterns remain in the relationships between the functions.

Systems perspective: The case company's production system is complex, with several plants of different types contributing to the overall system performance. Therefore, the organization finds it difficult to understand which initiatives are best for the overall system performance. Thus, the managers from each plant tend to prioritize their own plant, leading to sub-optimization.

Time and resources: Many of the employees are busy with daily operations. Although money is available for investments, there are no people that can work with them. Too many employees are busy with firefighting, and few have time to be involved in initiatives aimed at strategic development.

Goals and follow-up: The maintenance organization within the case company tends to focus on traditional goals, such as technical availability. Specifically, one primary goal is to maintain the same level of technical availability despite increasing plant age. Thus, formulating more inspiring goals is perceived as challenging. Furthermore, it is not easy to follow up on the initiatives and activities, as the effects are usually deferred.

Setting activities: The case company is determined to pursue development towards digitization and data-driven decision-making, as they perceive it to be critical to reaching the company's overall goals. However, it is perceived as challenging to set the specific activities that support the goals set on a management group level.

5. Recommendations

To overcome the hindering factors, Table 1 provides recommendations that target each of the six factors. The recommendations are based on insights obtained from the project, the researchers' experiences, and literature. We suggest that managers use the recommendations for preventing the hindering factors before implementation or reacting to the hindering factors during implementation.

Table 1. Hindering factors and recommendations.

Hindering factor	**Recommendations**
Leadership clarity	Formulate and communicate a clear vision. Clarify the relationships between ongoing and new initiatives as well as how these contribute to the vision. Clarify how concepts such as Smart Maintenance or Lean contribute to the vision and strategy.
Culture	Create incentives that stimulate innovative thinking and prevent the perseverance of old and less favorable cultural patterns. Establish routines where different roles are incentivized to collaborate. Take help from external parties that inspire and resolve old patterns, e.g. invited workshops to stimulate innovative thinking.
Systems perspective	Define an organizational unit where new initiatives are tested, followed by scaling it to the rest of the system. Agree on routines for prioritizing based on a systems perspective, and ensure that such routines are followed. Establish processes that encourage collaboration and knowledge sharing across different plants and organizational functions.
Time and resources	Ensure commitment from top management to gain access to necessary resources. Prioritize between improvement initiatives and create a clear strategic roadmap. Make sure that employees can formally report the time spent on different development initiatives.
Goals and follow-up	Set goals that focus on what to do in order to impact the desired dimensions of performance (i.e., leading indicators), e.g. goals for the number of data-driven decisions (leading indicator), and complement them with lagging indicators, e.g. goals for a certain level of technical availability. Invite employees to set their own individual goals that inspire them. Make sure that the individual goals are aligned with the overall goals of the maintenance organization and the company. Integrate the follow-up of Smart Maintenance and other initiatives with already established follow-up routines.
Setting activities	Involve employees in workshops – they usually have many ideas for improvements. Create an innovative environment where any suggestion is welcome. Emphasize quantity over quality – brainstorm activities that allow for meeting already formalized goals. Thereafter, prioritize the activities that are easy to start with and will have an impact. Get inspiration for prioritized activities by collecting input from external parties, e.g., study visits, consultants, and partners.

6. Discussion and conclusions

By means of an empirical case study within energy production, we identified six hindering factors that impede the implementation of Smart Maintenance, as well as proposed recommendations for overcoming them. This paper thereby contributes with in-depth insights that can be used by other companies in their Smart Maintenance implementation. We suggest that industry practitioners interested in pursuing Smart

Maintenance reflect upon these hindering factors and how they may emerge and influence their organization.

In light of the identified hindering factors and theoretical fundamentals of change management, we also make the overall interpretation that management commitment to Smart Maintenance was lacking in the case company. It is well-known that management commitment is necessary (critical, essential) for successful organizational change [9,26,27]. That is, managers must be committed to implementing Smart Maintenance in their organization. If management commitment is absent, it is a waste of time, money, and other resources to focus on anything else. However, the presence of management commitment does not guarantee successful Smart Maintenance implementation, because also other factors play a role. Thus, the hindering factors identified in this paper provide a set of clear obstacles that industrial companies may face in their Smart Maintenance implementation.

The work procedure for Smart Maintenance strategy development proposed by Lundgren et al. [19] is based on benchmarking of the maintenance organization. The benchmarking is done with a Smart Maintenance measurement instrument (SMASh) [22] that helps identify the current state of the maintenance organization and find specific areas for improvements. Thereby, it has the potential to help in overcoming the hindering factors. For example, it helps create a clear vision about Smart Maintenance, i.e. increases leadership clarity; it creates employee engagement that may change the culture and attitudes towards change; it helps set specific activities to prioritize, based on the organization´s current state and potential areas of improvement. Still, management commitment is vital to start and execute the Smart Maintenance strategy development process at all.

Most research about organizational change tends to focus on the preparation of the change, considering the actual execution of the change to a lesser extent [9]. Further, maintenance research has devoted too little attention to the organizational development needed for maintenance in a digitalized environment [8]. This paper contributes theoretically with the identification of six hindering factors and associated recommendations from overcoming them, which increase the understanding of antecedents of successful organizational change in maintenance.

For future research, we suggest replicating this study by including more companies from a larger variety of industrial sectors. This will contribute to a more generalized understanding of hindering factors that may emerge during Smart Maintenance implementation. We also suggest studies to further substantiate and empirically test the recommendations in Table 1. In addition, we also propose to investigate the relationship between the hindering factors and environmental contingencies (e.g., industrial sector, plant size, type of production process). Such studies may help in providing more individualized recommendations for industrial companies that are implementing Smart Maintenance.

In conclusion, industry practitioners can use the findings of this study to increase the likelihood of success in their Smart Maintenance implementation; specifically by reflecting upon the hindering factors in advance and choosing a set of appropriate countermeasures. Thus, this paper supports the implementation of Smart Maintenance and helps industrial companies developing sustainable and resilient production systems.

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References

[1] Hermann M, Pentek T, Otto B. Design Principles for Industrie 4.0 Scenarios. In: Proceedings of 2016 49th Hawaii International Conference on Systems Science; 2016 Jan 5–8, Maui, Hawaii. doi:10.1109/HICSS.2016.488.
[2] Kang HS, Lee JY, Choi S, Kim H, Park JH, Son JY, Kim BH, Do Noh S. Smart manufacturing: Past research, present findings, and future directions. International Journal of Precision Engineering and Manufacturing-green Technology. 2016; 3(1):111-128.
[3] Pessot E, Zangiacomi A, Battistella C, Rocchi V, Sala A, Sacco M. What matters in implementing the factory of the future: Insights from a survey in European manufacturing regions. Journal of Manufacturing Technology Management. 2021;32(3):795-819.
[4] Cimini C, Boffelli A, Lagorio A, Kalchschmidt M, Pinto R. How do industry 4.0 technologies influence organisational change? An empirical analysis of Italian SMEs. Journal of Manufacturing Technology Management. 2021;32(3):695-721.
[5] Groover MP. Automation, production systems, and computer-integrated manufacturing, Prentice Hall Press;2007.
[6] Bokrantz J, Skoogh A, Berlin C, Wuest T, Stahre J. Smart Maintenance: an empirically grounded conceptualization. International Journal of Production Economics. 2020;223:107534.
[7] Akkermans H, Besselink L, van Dongen L, Schouten R. Smart Moves for Smart Maintenance: findings from a Delphi study on 'Maintenance Innovation Priorities' for the Netherlands. 2016; World Class Maintenance.
[8] Silvestri L, Forcina A, Introna V, Santolamazza A, Cesarotti V. Maintenance transformation through Industry 4.0 technologies: A systematic literature review. Computers in Industry. 2020;123:103335.
[9] Stouten J, Rousseau DM, De Cremer D. Successful Organizational Change: Integrating the Management Practice and Scholarly Literatures. Academy of Management Annals. 2018;12(2):752-788.
[10] Culot G, Nassimbeni G, Orzes G, Sartor M. Behind the definition of Industry 4.0: Analysis and open questions. International Journal of Production Economics. 2020;226:107617.
[11] Lu Y. Industry 4.0: A survey on technologies, applications and open research issues. Journal of Industrial Information Integration. 2017;6:1-10.
[12] Nosalska K, Piątek ZM, Mazurek G, Rządca R. Industry 4.0: coherent definition framework with technological and organizational interdependencies. Journal of Manufacturing Technology Management. 2020;31(5):837-862.
[13] Grubic T. and Peppard J. Servitized manufacturing firms competing through remote monitoring technology - An exploratory study. Journal of Manufacturing Technology Management. 2016;27(2):154–184.
[14] Lee J., Ardakani H.D., Yang S., and Bagheri B. Industrial Big Data Analytics and Cyber-Physical Systems for Future Maintenance and Service Innovation. Procedia CIRP. 2015;38:3–7.
[15] Li Z, Wang Y, and Wang K-S. Intelligent Predictive Maintenance for Fault Diagnosis and Prognosis in Machine Centers: Industry 4.0 Scenario. Advances in Manufacturing. 2015;5(4):377–87.
[16] Roy R, Stark R, Tracht K, Takata S, and Mori M. Continuous maintenance and the future – Foundations and technological challenges. CIRP Annals-Manufacturing Technology. 2016;65(2):667–688.
[17] Compare M, Baraldi P, and Zio E. Challenges to IoT-Enabled Predictive Maintenance for Industry 4.0. IEEE Internet of Things Journal. 2020;7(5):4585–4597.
[18] Usuga-Cadavid JP, Lamouri S, Grabot B, and Fortin A. Using deep learning to value free-form text data for predictive maintenance. International Journal of Production Research. 2021. doi: 10.1080/00207543.2021.1951868.
[19] Lundgren C, Bokrantz J, Skoogh A. A strategy development process for Smart Maintenance implementation. Journal of Manufacturing Technology Management. 2021;32(9):142-166.

[20] Bengtsson M, Salonen A. On the need for research on holistic maintenance. In: 22th International Congress on Condition Monitoring and Diagnostic Engineering Management (COMADEM), 9-11 June 2009, San Sebastian, Spain. Fundacion Tekniker, p. 165-172.
[21] Tsang AH. A strategic approach to managing maintenance performance. Journal of Quality in Maintenance Engineering. 1998;4(2):1355-2511.
[22] Bokrantz J, Skoogh A, Berlin C, Stahre J. Smart Maintenance: instrument development, content validation and an empirical pilot. International Journal of Operations & Production Management. 2020;40(4):481-506.
[23] Veile JW, Kiel D, Müller JM, Voigt KI. Lessons learned from Industry 4.0 implementation in the German manufacturing industry. Journal of Manufacturing Technology Management. 2020;31(5):977-997.
[24] Dangayach G, Deshmukh S. Manufacturing strategy. International Journal of Operations and Production Management. 2001;21(7):884-932.
[25] Jarzabkowski P, Balogun J, Seidl D. Strategizing: the challenges of a practice Perspective. Human Relations. 2007;60(1):5-27.
[26] Kotter JP. Leading change. Cambridge MA: Harvard Business Press; 1996.
[27] Goswami M. Promoting fearlessness of change through social intelligence: mediating role of collective efficacy and moderating role of management commitment to change. Journal of Accounting & Organizational Change. 2021;doi: 10.1108/JAOC-05-2020-0064.
[28] Yin RK. Case study research and applications: design and methods. SAGE publications: Los Angeles; 2018.
[29] Eisenhardt KM. Building theories from case study research. Academy of management review. 1989;14(4):532-550.
[30] Gioia DA, Corley KG, Hamilton AL. Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. Organizational research methods. 2013;16(1):15-31.
[31] Elo S, Kyngäs H. The qualitative content analysis process. Journal of advanced nursing. 2008;62(1):107-115.