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IFAC PapersOnLine 53-3 (2020) 95–100

Organisational Constraints in Data-driven Maintenance: a case study in the automotive industry

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Abstract: Technological development and innovations has been the focus of research in the field of smart maintenance, whereas there is less research regarding how maintenance organisations adapt the development. This case study focuses to understand what constraints maintenance organisations in the transition into applying more data-driven decisions in maintenance. This paper aims to emphasize the organisational challenges in data-driven maintenance, such as trustworthiness of data-driven decisions, data quality, management and competences. Through a case study at a global company in the automotive industry these challenges are highlighted and discussed through a questionnaire survey participated by 72 people and interviews with 7 people from the maintenance organisation.

Keywords: Maintenance Management, Decision Support, Data Quality, Data-driven Decisions, Organisational Factors, Smart Maintenance

1. INTRODUCTION

The manufacturing industry is changing rapidly, and technological innovations are pushing the current practices for maintenance organisations forward with developments in areas such as digitalisations, big data, Internet of Things (IoT) and predictive maintenance. These innovations show promising improvements for maintenance organisations around the world. Modernised maintenance operations, often referred to as Smart Maintenance can impact the performance of the manufacturing plant. Data-driven decision making is even considered one of the dimensions of the Smart Maintenance concept (Bokrantz et al., 2019). The ongoing increase in available data from machines in the manufacturing companies improves maintenance organisations' prerequisites in taking more data-driven decisions than experience-based decisions (Muller et al., 2008). Advantages of data-driven decisions are that it can result in improvements in terms of productivity and resource efficiency for maintenance organisations (Li & Ni, 2009).

While extensive research has been performed in developing technical aspects of smart maintenance and data-driven decisions, less research has been performed regarding organisational and managerial factors. With digitalisation of maintenance organisations, companies worldwide are faced with the challenge of successfully implementing and maintaining new technologies to exploit their advantages. According to Frazer et al. (2015) there is a gap between what is practiced in industry and what is developed in research, which highlights that there is a need for more research in order to understand the constraints within maintenance organisations for implementing current research.

Implementing new technologies is a continuous challenge for organisations across different industries in their strive to keep up with the latest research and ahead of competitors. This implies that changes are going to be performed in the organisation and that new competences will be necessary. In order to realise change Thomas & Hardy (2011) write that change is strongly dependent on the level of participation from the people within the organisation, and that it is crucial to have a highly engaged and committed management to sustain change. Specifically, in regard of digitalisation, Bokrantz et al. (2017) suggests that securing competencies and competence development is a long-term challenge for maintenance organisations. Other challenges noted are as Vogl. et al. (2016) suggest, that user-friendly digital systems have an impact on the extent with which the organisation uses it. In addition, lack of data quality can have negative effects on the organisational culture (Ryu et al., 2006). It means that it becomes difficult to build trust data in the organisation, which may imply a lack of stakeholder's acceptance of any initiatives based on such data (Haug et al., 2011). Thus, this creates challenges during the data utilization process and causes delays in decision-making in maintenance (Aljumaili et al., 2018).

The scope of this paper is to empirically explore if organisational and managerial factors constrain the implementation of digitalisation within maintenance organisations. Additionally, to provide knowledge about the organisational challenges in data-driven maintenance. To achieve this the study was performed as a case study in a global company in the automotive industry, with the following research question: "*What are the organisational requirements and constraints of data-driven maintenance?*".

10.1016/j.ifacol.2020.11.015

2. THEORETICAL BACKGROUND

Management of maintenance organisations can be a complex task, but through digitalisation of production systems both Manufacturing Execution Systems (MES) and Computerised Maintenance Management Systems (CMMS) aid in simplifying the work and are important tools that support in decision making (Mehta & Reddy, 2015). These systems gather real-time data from the plant and this data can be used for resource allocation, track maintenance activities, daily planning of maintenance and identifying crucial issues (Mehta & Reddy, 2015). Knowledge extracted from the data coming from these systems enables a higher transparency of the production systems and helps manufacturers on more rational, informed, and responsive decision-making (Alcácer & Cruz-Machado, 2019). In summary, digitalisation in maintenance organisations has led to more data being available which in turn can improve decision making processes with more facts. Despite the growing trend of using analytics and data-driven solutions in maintenance, Guo et al. (2017) argue that it is still common that decisions in maintenance organisations are experience based. Even though experience of employees is useful, decisions based on data rather than on experience could drastically improve reliability, resource allocation and productivity as shown by Li & Ni (2009).

Beyond the growth of digitalisation and support systems, equipment is more connected through IoT which provides more data about the machine status. Maintenance organisations have more power to analyse and understand data for prediction of machine conditions through the accessibility of more data and the rise of data analytics (Roy et al., 2016). Moreover, development of the algorithms to identify bottlenecks show the promising results in prioritisation of maintenance, reducing the maintenance costs as well as improvement of the productivity (Li & Ni, 2009). However, there is a risk related to data quality. If it is not being sufficient, it can result in misleading data and wrong decisions being taken, thus impeding positive effects of data-driven decisions (Cai & Zhu, 2015).

Windt et al. (2019) explains that transforming into a data-driven organisation is a hard and crucial task, where it is critical to communicate and highlight the value of data-driven decision making within the organisation. In addition, the companies with a data-oriented culture are more likely to use data-driven decisions in future decisions according to Kiron et al. (2011). It is important to manage transformations well, as a common obstacle is the resistance to change and will lead to a lack of people within the organisation (Kotter, 2007). This change is strongly dependent on the participation of people in the organisation.

Managing comeptences in digitalisation is an important issue, where the lack of competences in maintenance organisation is a constraint for the transformation becoming more data-driven (Pellegrino et al., 2016). Where challenges in retaining the right competences in data analytics is identified to be a common problem (Windt et al., 2019). Additionally, Ghasemaghaei et al. (2018) express that the level of competence within data analytics is a major contributor to the efficiency of decisions based on data, where Kiron et al. (2011) highlight that the important skills are information management and analytical skills among the others.

3. RESEARCH METHOD

The research was performed as a case study in the maintenance organisation at the production plant in a global automotive company in Sweden. The study was designed using a mixed methods approach, in an explanatory sequential design (Creswell 2014). The research required the research design to acheive a quantitative base for the study which would be further explained by a qualitative study. In the explanatory sequential design, the quantitative data was collected and explored to provide answers which later would be explained and interpreted in depth by the qualitative data. Due to this case study being an early study in organisational constraints in maintenance, with the aim to increase research in this area, the quantitative data was explored solely with descriptive statistics. For future research studies the authors recommend a more statistical rigid analysis of the data to further strengthen the results.

3.1 Case study

Criteria for the selecting company for this case study were that the company represents a global context, are developing practices in data-driven decisions in maintenance and have technological capabilities for data-driven decision making.

The company chosen has its own data science organisation for supporting departments with data analytics. They are motivated in developing their practices and have implemented several tools for data-driven maintenance. Previously the company in the case study has collaborated with academia in the development of a framework for data-driven maintenance. Despite the collaboration of technological advancements, the organisation has not adapted more data-driven approaches. Therefore, the purpose of this case study was to investigate the maintenance organisation's readiness for adoption of data-driven decisions in maintenance. By that means it was investigated how the organisational structures, workforce, culture, and existing data affect the use of data-driven decision support and the ability to adapt to new smart maintenance developments.

The case study was initiated with a pre-study which was followed by a quantitative study, qualitative study and analysis of the findings as shown in Figure 1.

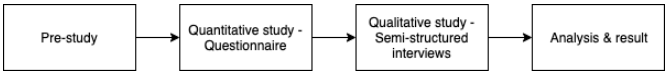

Fig. 1. Research design

The pre-study aimed to provide an understanding of the current situation in the company and to form the research question. The pre-study's foundation was based on literature

review and a small series of interviews with maintenance engineers at the company which had broad knowledge and deep insight in the maintenance work in the factory. Based on the pre-study, the research question was formed. To investigate and to answer the research question, based on literature, four hypotheses were tested in the quantitative and qualitative study. Firstly, when shifting to new work methods or implementing new computer systems, the workforce may oppose the change if there is a lack of trust to change (Kotter, 2007; Thomas & Hardy, 2011). Secondly, lack of competence development in an organisation is a constraint for working more data-driven (Pellegrino et al. 2016). Thirdly, the extent of using digital support systems and the use of data-driven decisions are impacted by the user-friendliness of digital support systems (Vogl et al., 2016). Lastly, the decision outputs of data driven decision-making are often highly reliant on the quality of the data (Brous et al., 2020). Therefore, a lack of data quality influences stakeholders to develop trust and in turn the use of data by decision-makers (Brous et al., 2020).

3.1.1 Quantitative study

The quantitative study was performed through a questionnaire with 34 questions, which had 72 respondents of 271 employees from the maintenance organisation. The aim of the questionnaire is to test the stated hypotheses and to identify areas where which constraints data-driven maintenance. Based upon the pre-study and literature review, four topics were identified including several questions that could describe constraints. These topics are *change management*, *competencies, data-driven decisions,* and *support systems.* To reach as many of the selected groups as possible, the questionnaire was formed as a web-based questionnaire sent directly by email. For each question, a five-point Likert-scale was used, which made it possible to do a statistical analysis. The respondents had the following answering alternatives; "*strongly agree", "agree", "neutral", "disagree", "strongly disagree"* (Creswell, 2014). However, in this study the respondents were provided with a sixth alternative, "*don't know*", which could be used when none of the alternatives in the Likert scale agreed with the respondent's opinion. To gain information from people within different parts and levels of the organisation, the selected group of respondents was distributed between technicians, engineers, and managers from the maintenance organisation. To get a detailed understanding and the possibility to compare different groups, the respondents were clustered depending on role and department. The questionnaire was given to all 271 employees in the organisation to get as many answers as possible.

3.1.2 Qualitative study

To get a deeper understanding and nuance of the results in the quantitative study, a qualitative study was conducted through performing seven interviews. The interviews were organized in a semi-structured way and added into a deeper perspective from people divided into four groups based on their roles such as maintenance technician, engineer, manager, and planner. The interviewees were chosen to get a holistic view of the situation answers through a range of perspectives from engineering, management, and the daily maintenance operations. The specific people were chosen based on their role in the organisation.

Executing the interviews with a semi-structured approach meant asking predetermined questions and having the flexibility of going deeper into answers and topics that were of extra interest for the study (Creswell, 2014). The questions to be answered in the interviews were based on the findings from the questionnaire and were divided into four sections which complemented the questionnaire results; data-driven decision making, support systems, competences and change management. Each section consisted of questions that were asked to nuance and to get deeper knowledge in the questionnaire results. The advantage of this approach is that it made it possible to develop an understanding for the underlying reasons of the questionnaire results, to either confirm the results or to further explore, and identify similarities and discrepancies between different roles in the organisation and

4. RESULT AND ANALYSIS

The results and analysis are divided into three parts and presented in the following titles, such as the results of the questionnaire, the results of the interviews and overall results based on a combined analysis.

4.1 Questionnaire

According to the answers to the questionnaire many of the respondents believe there are benefits in transitioning the maintenance organisation into being more data-driven in decision making, as seen in Figure 2. However, even though most people agree or strongly agree that there are benefits of data-driven decisions, many respondents are hesitant towards their trust to data-driven decisions, where 42% agree that they do not trust data-driven decisions in maintenance.

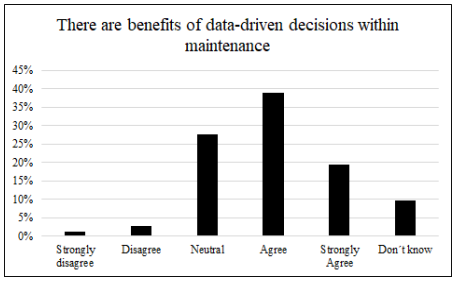

Fig. 2. Distribution of the answers regarding the benefit of data-driven maintenance.

Regarding how decisions are taken, the respondents believe decisions are based more on experience rather than on data as seen in Figure 3. Altogether the answers of the three questions show that even though people believe there are benefits in data-driven decisions, most of the decisions are based on experience. This could partially be explained by that

people are insecure regarding the trust towards data-driven decisions.

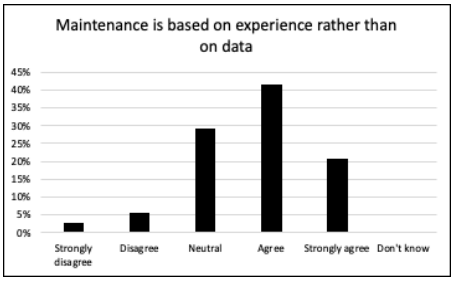

Fig. 3. Distribution of the answers regarding decisions within maintenance.

There is a lack of consensus regarding if the systems such as CMMS and MES provide enough support for the maintenance work, where a majority of the respondents are either neutral or disagreeing. These answers open for questions regarding the usability of the systems and if employees have enough competences in the systems. On the other hand, 60% of the respondents answer that they have enough competences for working more data, while they are more unsure if the organisation has enough preconditions for a transition, where 65% are unsure or think the preconditions are lacking. There might also be other structural issues that question if there are enough preconditions, however, on an individual level it seems that people have enough competences for the transition.

The questionnaire shows that a major part of the people in the maintenance organisation agree that implementing new developments and technologies are important for good maintenance work as it is demonstrated in Figure 4. However, there is a lack of consensus regarding the trust towards changes, where 49% of the respondent's trust to changes is less positive than the belief that changes bring benefits. The difference between the agreement of benefits and the trust to changes could indicate that there might be challenges in the implementation of changes, which needs further explanation. Moreover, questionnaire results indicate that none of the employees in the local maintenance organisation did know about the earlier implemented digital support tool in the CMMS system which was implemented after the company's involvement in a research project. The underlying reasons for the failed implementation also need further investigation.

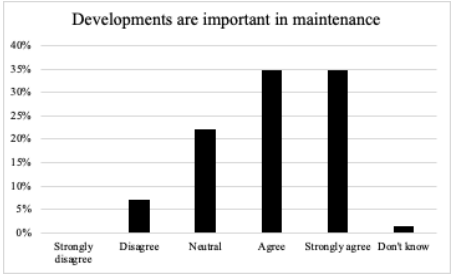

Fig. 4. Distribution of the answers regarding the view of benefits to change.

4.2 Interviews

The qualitative study highlighted that a constraining factor for increasing the use of data is the perception that the data quality is insufficient. The general view is that there is a lack of data quality, however there is lacking consensus whether the data quality is insufficient or if it is only perceived to be insufficient. What became pronounced in the interviews is that people in the organisation tend to resort into relying on experience rather than on data. The insecurity about the data quality and the lack of data in the CMMS could be reasons to why there is a lack of trust in the support systems. It is suggested that data is an important basis for decisions, however the level of use varies. Despite that the use of data varies, there is a consensus that the maintenance organisation would benefit from more data-based decisions.

Regarding the digital support systems there is a consensus that the CMMS is time consuming and difficult to use. It has resulted in people being hesitant towards using the support systems, and instead creating their own tools to cover the lack of support, which increases the risk that different data is extracted for measuring the same thing. Further, the support tools implemented in a previous research project was suggested by interviewees not to be used because of a lack of awareness and knowledge in the project, which shows that implementation of changes sometimes are missed.

The general view is that the level of competence within the maintenance organisation is sufficient, however it is suggested that some key competences in data analytics might be missing in future efforts in utilising data within maintenance. In general, there is no consensus in whether the company is putting enough resources into competence development. It is described that competence development in data and the support systems to a big extent is shared between colleagues instead of any formal education provided by the company.

There is a common view among the employees that the change management practices need to be improved, and that there is a lack of confidence and commitment to participate in new changes. The perception is that the management is focused on the quantity of development projects rather than a sustainable implementation. Additionally, people tend to lose commitment to changes due to long implementation processes and since the management fails in communicating the benefits. However, despite the perception that management fails to commit the organisation to changes, there is a positive mindset and strong belief in the need for continuous development. What seems to be needed is stronger communication between different levels within the organisation to increase the understanding of the challenges and doubts faced by different people.

4.3 Overall results

In this section, the results from the questionnaire and interviews are combined to answer the research question. The questionnaire showed that the majority of the participants agreed with the benefits of data-driven decision making. Whereas in the interview, we identified the existing problems in the support systems that hinders a data-driven approach. Together, we conclude that maintenance organisations intend for a transition into taking more data-driven decisions, which is important and could bring benefits.

Moreover, the questionnaire results showed that a large part of the participants do not trust the current data-driven decisions. In the interviews it could be identified that the lack of trust was due to a lack of data collection and lack of reporting of data due to difficulties in operating the support systems, which makes people insecure whether the data represent the reality. Further, there is a negative view about data, and we identified that people resort into basing decisions on experience rather than data to cover the lack of trust. This brings us to the conclusion that to increase the trust to data driven decisions there is a need to increase the amount of data collected and to overhaul the support systems. Regarding the readiness for the transition into taking more data-driven decisions, the questionnaire results showed that a majority think that the preconditions are poor. This is explained by the interview results, where it could be identified that there is a general need for training in data analytics to be able to make data-driven decisions.

In both the questionnaire and the interviews, the respondents agree that changes have a vital impact in the maintenance organisation, as explained in the interviews, that changes are important for staying competitive and improving current practices. On the other hand, according to the questionnaire results, the organisations confidence in how changes are implemented is lower. From the interviews the lack of confidence could partially be explained by the management's lacking ability to commit people to participate in change processes. With this in mind come to the conclusion that change management practices are constraining implementation, which could constrain future transitions into becoming more data-driven.

5. DISCUSSION

The research question asked for this case study was "*What are the organisational requirements and constraints of data-driven maintenance?*". The study does not show that one sole factor is the constraint for the organisation's transition into becoming more data-driven, but rather a combination of constraining factors. Combining lack of competences, poor data quality, digitalised systems which are hard to use and inadequate approaches to implementing new systems, the organisation has a hard time to transition towards a data-driven future.

Currently in the organisation employees tend to rely on experience instead of data in decision making, even though they see benefits of working more data-driven. The identified problem is the lack of perceived or actual data quality and flaws in the user-friendliness of the support systems. Although an employee's experience is important, it could also lead to biased perspectives and wrong prioritizations in the maintenance work. The lack of trust towards data is an issue that Brous et al. (2020) also identifies as a contributing factor to less use of data-driven decisions.

Even though the employees in the studied organisation have a positive view of the benefits of changes there is a skepticism towards implementation of them. The change management approaches in the organisation is one factor that constraints a transition into becoming more data-driven, where some changes are not sustained in the whole organisation due to lack of commitment and communication, which is a commonly identified issue in change management (Thomas & Hardy, 2011). Specifically, in digitalisation Windt et al. (2019) writes that change management is an important area for successful transitions into becoming more data-driven.

In retaining an implementation, competence is an important area. At the studied organisation competences and competence development is more seen as a future constraint for when data-driven approaches are more common. There is a view that not securing future competences in data analytics is a constraint for the maintenance organisation in implementing practices such as predictive maintenance. This view is shared by Windt et al. (2019), who writes that securing competences in data analytics and digitalisation is a common challenge in the industry.

The constraints identified in this study could be constraining factors for maintenance organisations in implementing smart maintenance developments such as predictive maintenance or bottleneck identification through algorithms for prioritising maintenance. If maintenance organisations do not take actions and adapt their organisations and their managerial practices, they might not be able to fully exploit the benefits of these developments in smart maintenance. This will in turn further widen the gap between research and industry.

In summary, this study has shown there are plenty of constraining factors that limit the extent data is used in decisions and the use of digital support systems. Other research studies such as a study by Bokrantz (2017) have presented some problems that were found in this study but without empirical evidence. We have found empirical evidence regarding constraints to data-driven decisions specifically in the field of maintenance. This study contributes to research with a case that highlights constraints for working and transitioning to data-driven decisions within the domain of maintenance organisation and specifically in the automotive industry. The findings could be generalised for maintenance organisations in general with additional studies in more manufacturing companies. However, we have shown that there is a need for further research into the soft aspects of implementing digital solutions, i.e. identifying the organisational constraints with data-driven decisions in maintenance organisations. We believe that with proper implementation and usage of data-driven solutions by

overcoming these constraints manufacturing companies can achieve long-term effect on business results.

6. CONCLUSIONS

Digitalisations of organisations are happening worldwide, and maintenance organisations are not an exception. Smart maintenance practices are pushing for using more data-driven approaches in maintenance. Our study aimed at identifying organisational requirements and constraints of data-driven maintenance implementation in manufacturing companies. Through this case study and applying a mixed-method research approach we identified that maintenance organisations face challenges in the transition to become more data-driven. The challenges identified were not purely technological but also organisational and managerial. We identified the constraints within *support systems*, *data quality* effects on organisational trust, *change management* approaches and development of *competencies*. The constraints were not mainly confined in their own area but seemed to interconnect and amplify each other. From the results we conclude that to achieve data-driven decision making in maintenance organisations, strong commitment, aim and focus from the top management is necessary in addition to technological advancements to ensure high quality data. The results of the study point towards future research in the soft aspects of data-driven approach implementation.

ACKNOWLEDGEMENT

The data presented in this article were collected when the first author and second author were writing a thesis at Chalmers University of Technology. The authors would like to thank Martin Johansson for his guidance, the people at the studied maintenance organisation, and the company involved.

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