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Procedia CIRP 119 (2023) 521–526

www.elsevier.com/locate/procedia

33rd CIRP Design Conference

Design for an integrated knowledge management policy for railway maintenance: An industrial synopsis

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Abstract

The European rail industry has undergone a shift in its overall knowledge management (KM) policy. Since liberalisation in the 1990s, rail operators have moved from obtaining the right train for the organisation to working with product manufacturers and infrastructure managers to procure new trains. In the past, maintenance engineers and technicians had more control over the design and procurement of trains. The new approach stresses more on co-designing to ensure that purchased trains can be adequately maintained and on the long-term effectiveness of maintenance plans. This requires new ways to train maintenance personnel based on prescribed (rather than internally developed) maintenance plans and establishing new roles and responsibilities. Combined with retiring experienced personnel, prevailing silo mentality culture and increasing train digitisation, this calls for designing a more efficient KM system to manage maintenance-related information.

This paper examines current practices and KM systems used within the Netherlands Railways maintenance department and identifies key challenges for organisational learning. Based on the literature review and practical insights, the authors propose a refined design of an integrated KM policy for designing maintenance-related KM systems. The proposed insights can bridge the scientific gap on how to approach KM research problems from the practical maintenance world.

Keywords: Integrated Knowledge policy; Knowledge management, Maintenance operations; Railways

1. Introduction

With the growing need to manage systems holistically to cope with changing risks in the transport sector, organisations today increasingly rely on the digitalisation of their processes [1]. While technology provides the means for rapid and effective migration of day-to-day organisational processes to digital means, in many cases, the workforce finds such initiatives unnecessary or difficult to implement. Moreover, despite good intentions, digitisation in organisations often starts in silos without involving the full user chain in the process. This leads to a common research problem in knowledge management, where developed technological solutions for managing organisational knowledge are insufficiently utilised and not fully embraced by the workforce [2]. This is especially the case when the use of such solutions is voluntary or when the organisational workforce uses other, faster means to get the job done. On the other hand, if the use of such a system is mandatory, the solutions developed need to be updated to incorporate wide-ranging user needs that should have been considered in the initial stages of the design process. This points to the need of having an integrated knowledge management

10.1016/j.procir.2023.02.147

policy for designing and implementing knowledge management solutions in organisations.

Practical insights have shown that employees struggle to recognise the value of digitisation of processes in their daily work and are consequently hesitant to fully embrace digitisation efforts in their work domain. Moreover, digitisation is often seen as a top-down activity and one intended to facilitate decision-making at higher levels of management, rather than as a means of the overall process and efficiency improvement at all levels of the organisation. Against this practical and scientific background, the authors in this paper investigate the research problem of knowledge embraceability and present an integrated knowledge management policy for the maintenance departments of the Dutch railway sector. By investigating this research problem, information and knowledge systems can be designed with a keen understanding of the digitalisation embraceability problem and developed and tested to address the embraceability challenges identified in this paper.

The paper is structured such that the theoretical foundations of the stated research problem are presented in section 2. The practical insights from the maintenance management department of Netherlands Railways are outlined in Section 3. Section 4 presents the design of the proposed integrated knowledge management policy in light of the provided theoretical and practical insights. The validation of the proposed policy design is provided in Section 5. Finally, a comprehensive discussion of the proposed policy design and a conclusion are presented in Section 6.

2. Literature review

Knowledge management as defined by [3] is “achieving organisational goals through the strategy-driven motivation and facilitation of (knowledge) workers to develop, enhance and use their capability to interpret data and information (by using available sources of information, experience, skills, culture, character, etc.) through a process of giving meaning to these data and information”. The management of knowledge has become increasingly more important for organisations driven by ISO certification requirements [4]. In this context, being a highly legislated sector, knowledge management holds primary importance for the railway sector.

Adequate knowledge management within a complex socio-technical system, such as the railway system, is no easy task and requires delicate sensitivity to several factors. For instance, [5] stressed that aligning knowledge management strategy with business strategy is crucial to the success of knowledge management. When it comes to formulating a knowledge management strategy, [6] noted that a technology-push approach has serious limitations and stressed that the development of a knowledge-sharing culture is needed for effective knowledge management.

According to [7], most problems in knowledge management processes occur in the knowledge acquisition, knowledge codification and knowledge dissemination phases - of the knowledge management process. Prior research in the Dutch railway sector has shown that employees prefer a process-oriented knowledge-sharing focus for inter-organisational knowledge domains and a content-oriented knowledge-sharing focus for intra-organizational knowledge domains [8]. Incorporation of such insights in the overall knowledge management policy of an organization, such that it aligns with the business strategy, is key to designing integrated knowledge management policy and systems.

Research conducted into individual knowledge-sharing behaviours towards knowledge management systems has shown that individual behaviour is motivated by organizational-culture dimensions and the system's technical characteristics [9]. Therefore, any proposed knowledge management policy for maintenance management should incorporate the organisational culture and system technical aspects (and their procurement approach) into account. This paper uses these theoretical insights as building blocks for the proposed knowledge management policy for railway maintenance management. The practical insights from the use of knowledge management systems within Netherlands Railways are outlined next.

3. Practical insights from the Netherlands Railways

The maintenance department of the Netherlands Railways has undergone a shift in its overall knowledge management over the past 30 years. National railway companies in Europe were split into rail operators and infrastructure managers in the late 1990s in line with EU legislation to support market competitiveness. On the one hand, this promoted market competitiveness and the digitalisation of trains; on the other, it resulted in a fragmentation of essential railway knowledge and staff into different organisations. Consequently, each of the newly developed organisations was driven by its objectives and KPIs. Combined with this, the increasing digitalisation of trains and the tightened legislation for maintenance management of trains resulted in the shift in the procurement approach of the Netherlands Railways for purchasing new trains. It shifted such that the rail operators no longer were in charge of the design process of new trains and procured the train required for their organisation but instead adapted the organisation for the new trains. Not only did the railway company's engineers and technicians no longer have central control over the overall design process of new trains but they also had to recruit new experts, in the electromechanical and software fields, and train the current professionals, for these areas, to properly perform the required tasks. These changes led to the following two major evolutions within the Netherlands railways:

- The digitalisation of organisational processes associated with maintenance management following the relevant regulation
- Introduction of new knowledge management systems (KMS) to manage key knowledge related to core maintenance management tasks.

Scientific insights acknowledge that the digitisation of organisational processes and the introduction of knowledge management practices can improve overall system performance [1], [10]. At the same time, however, practical insights also show that implementing such changes alone

cannot produce the desired results unless the professionals involved fully embrace such changes.

Training the organisation's staff for new digitalised ways of working is not an easy task. It requires not only a keen awareness of user needs and the prevailing organisational culture but also a comprehensive knowledge policy for the successful embracement of these changes. Considering these practical insights and presented theoretical insights, the authors propose an integrated knowledge policy for railway maintenance management.

The proposed knowledge policy aims to help railway organisations formalise an integrated knowledge management plan for carrying out the maintenance of their rolling stock fleet in line with the latest Entity in Charge of Maintenance (ECM) legislation (VO779/2019). This legislation recommends four different functions which are as follows:

- Management is ultimately responsible for coordinating and supervising the execution of all maintenance functions and ensuring the safe condition of rolling stock within the railway system.
- Maintenance development is responsible for managing maintenance documents based on operational design data and performance and learning from practice.
- Maintenance planning is responsible for ensuring that rolling stock is taken for maintenance and operation and returned to service after maintenance. This includes the compilation and assignment of maintenance work packages.
- Execution and release of maintenance that is responsible for carrying out maintenance as prescribed.

Establishing appropriate knowledge roles and responsibilities for all these four functions is central to any successful knowledge policy for railway maintenance management. Practical insights gathered through preliminary informal discussions showed that there are currently too many administrative layers for simple tasks and operational problems. In addition, the prevailing silo mentality [11] and technological findability issues [2] make organisational learning difficult to achieve.

Given the shift in procurement approach and Netherlands Railways' commitment to operate and maintain rolling stock in-house, the maintenance management of the rolling stock fleet occupies a central position within the organisation. Purely from a maintenance management perspective, the organisation aims to:

- Ensure the long-term functioning of the prescribed maintenance plans
- Flawless execution of the prescribed maintenance tasks in a cost-effective manner
- And the maximum utilisation of the product's life, developments in technologies, and personnel expertise to carry out the prescribed maintenance.

In this context, an integrated knowledge policy that can specify the role of new technologies and personnel expertise within the overall organizational goal and vision for maintenance management can help address new challenges in rolling stock maintenance.

4. Proposed design for integrated knowledge management policy

The proposed design sheds light on the role of organisational goal and vision in steering key evolutions within the current railway organisations as shown in Fig. 1. When considering the digitalisation of trains, learnings from all four functions of ECM must be incorporated during the formulation of an organisational procurement policy for new trains. This is only possible when the organisation as a whole values knowledge sharing and ensure that proper organisational processes are in place to facilitate both formal and informal knowledge sharing across all maintenance-related departments.

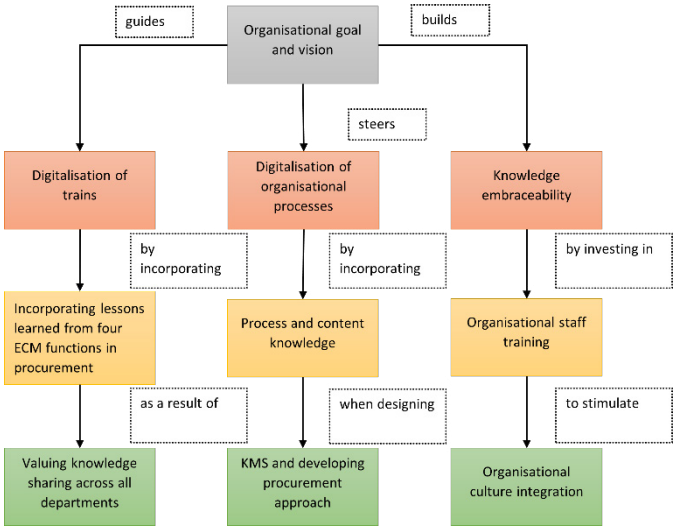

Fig. 1. Proposed knowledge management policy design.

The digitalisation of organisational processes should also be steered from organisational vision such that due attention is paid to both process and content knowledge. Earlier research conducted within Netherlands Railways demonstrated that organisational staff prefers having process-related knowledge-sharing approach for inter-organisational knowledge domains and content-related focus for inter-organisational knowledge domains [8]. This is mainly because decision-making within the organisation requires approval from a lot of stakeholders and hence requires process knowledge about those decision-making processes. In comparison, when dealing with stakeholders from other organisations, the organisational members are mostly concerned with getting alignment on the content of discussed knowledge domains and hence require prerequisite content knowledge. Prior research has also shown the utility of using the Design Science approach in addressing knowledge findability issues in the Dutch railway sector and resulted in enhanced collaboration and knowledge sharing [2].

Taking into consideration these insights KMS must be designed and developed with an understanding of such needs of the maintenance personnel as stressed in the proposed policy design. Similarly, the developed procurement approaches should also ensure that adequate agreements are made with

external parties, such as suppliers and sub-suppliers, on knowledge sharing of relevant knowledge domains.

The proposed design also stresses that organisational goals and visions should build knowledge embraceability. This can be achieved, for instance, by investing in organisational staff training for new developments in the maintenance field and raising awareness on functionalities of incorporated KMS. Similarly, knowledge embraceability can also be built by stimulating organisational culture integration within the railway sector. With the growing demands for higher punctuality, safety and comfort by the governments, railway organisations need to culturally endorse proposed improvement changes to guarantee that they are embraced at an individual level.

By collectively addressing ongoing digitalisation efforts and the issue of knowledge embraceability in the organisation's goal and vision, management can ensure that the development and implementation of new information and knowledge systems are supported and driven by the organisation's employees. This, in turn, can help prevent the silo digitalisation of processes and development of information and knowledge management systems, as overall system integration between the systems used for managing and sharing organisational knowledge is the backbone of knowledge embraceability and validity.

Finally, management's determination and affirmation to address the digitisation of processes and knowledge embraceability simultaneously through a common goal send the right message to the organisation's staff and communicate the seriousness of addressing the underlying issues associated with knowledge sharing and organisational culture integration. This is important to create the ripple effect needed for the widespread adoption of new information and knowledge management systems.

5. Validation

To validate, the proposed design was shared with the maintenance engineers in the Dutch railway sector through an online survey. The survey was designed to validate the necessity, completeness and potential usefulness of the proposed knowledge management policy. The target group of the survey consisted of maintenance engineers working in the Dutch railway sector who had experience in the maintenance management of the Dutch rolling stock fleet. This criterion made them suitable candidates for the analysis of the proposed policy, as they had in-depth knowledge of the overall maintenance planning, maintenance execution and maintenance policy of the rolling stock fleet. Moreover, they also had experience in working with different knowledge management systems to carry out the overall maintenance management process. The redacted and translated version of the shared survey (originally in Dutch) is shown in Appendix A. As Appendix A shows, the maintenance engineers were invited to review the proposed policy design and provide feedback on how to further improve the developed policy, from the following perspectives:

- Indicating whether they consider it necessary to prepare such a policy design;
- Indicating which aspects are missing in the policy design;
- Indicating which maintenance management challenges such a policy could overcome and suitable cases for the policy's application to test its usefulness.

The responses were received in two ways: as an e-mail response to the shared survey and through an informal discussion after a presentation in the knowledge-sharing meeting (where, among other things, the policy was presented). All responses received were processed and categorised based on the three perspectives mentioned above, namely the necessity, completeness and potential usefulness of the proposed knowledge management policy. Some of the key points from the responses and feedback received on the mentioned perspectives are presented as follows:

- The necessity of a knowledge management policy.

The need for such a policy was endorsed by the maintenance engineers. For instance, one of the maintenance engineers stated: *"I think a policy document, without making it too big, does justice to our ECM2 responsibility"*. They also noted that such a policy can help them reach at least the low-hanging fruit when it comes to addressing prevailing problems with knowledge management and organisational culture integration.

- Aspects missing from the proposed design.

The responses gathered reported that the focus of the embraceability aspect should be more on the people side than on the technology side and that it should be reflected in the organisation's goal and vision. In the words of one of the maintenance engineers: Due to the unpredictability of these kinds of developments and their impact on the organisation, it is sometimes difficult to determine what skills employees should have (in the long term). It is very important to accept and embrace these kinds of uncertainties, so to speak, and respond accordingly. In doing so, you do not put technology at the centre, but people. In my opinion, this means focusing on the agility of your staff. How do you weave this into strategy and policy (and also into the organisational culture mentioned earlier)? A loop back to objective and vision.

- Challenges that can be overcome and suitable cases for the application.

Finally, the feedback gathered revealed that the proposed policy design could first initiate a discussion on the embraceability of stored documents, such as reference documents, in already used KMS. This could help identify ways to improve the embraceability of such knowledge within the team. It was further pointed out that in a multi-stakeholder context, it is often difficult to align conflicting interests. It was noted that such a policy design could help align interests in such environments.

The responses collected were processed and incorporated into the revision of the proposed design. As a result of the insights, the proposed policy design was revised and three feedback loops were added, as shown in Figure 2.

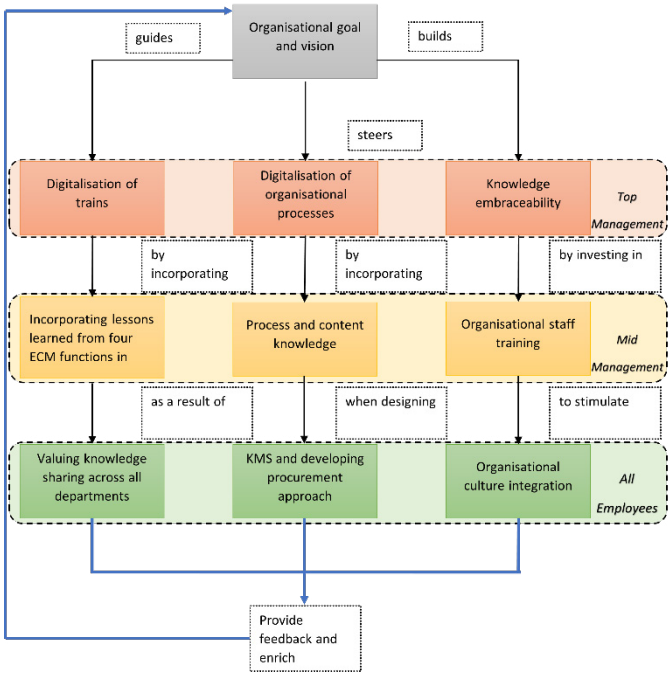

Fig. 2. Revised knowledge management policy design (the blue lines indicate the changes made to the design after incorporating the validation insights).

One of the main differences between figures 1 and 2 is the three feedback loops added (shown in blue in figure 2). During the follow-up discussion after the knowledge-sharing meeting, it became clear that the organisation's goal and vision also need continuous improvement and are not a one-off activity. This observation led the authors to include three feedback loops in the original policy design. This inclusion ensures that valuable insights gained as a result of multi-stakeholder knowledge sharing, the use of newly designed knowledge management systems and procurement approaches, and cultural integration efforts are included in the continuous improvement of the developed organisational goal and vision.

To clarify the roles and responsibilities for the identified tasks and challenges, Figure 2 also sets out three layers of responsibilities. Since top management oversees and shapes organisational policy holistically, Figure 2 suggests that challenges such as digitalisation of trains, digitalisation of organisational processes and knowledge embraceability should be primarily addressed by top management. Similarly, since middle management is more closely involved in the day-to-day management of problems, Figure 2 suggests that it is middle management responsibility to oversee tasks such as the training of organisational staff and the integration of lessons and process and content knowledge. Finally, given the holistic commitment required for tasks such as valuing knowledge sharing across all departments, designing KMS and procurement approaches and stimulating organisational culture integration, Figure 2 suggests that all staff share responsibility for these tasks.

6. Discussion and conclusion

To meet the growing demand for the digitisation of organisational processes and the introduction of advanced knowledge management systems for successful knowledge valorisation, this paper outlines an integrated knowledge management policy for railway maintenance management. In this context, the paper first identifies the main ongoing digitalisation efforts in the Dutch railway sector, namely the digitalisation of trains and the digitalisation of organisational processes. Based on theoretical and practical insights, the paper then identifies the embraceability problems in the large-scale implementation of digitalised solutions for organisational processes and newly developed information and knowledge management systems. It then elaborates on the current practical problems often experienced in implementing the roles and responsibilities prescribed in the latest European legislation ECM (VO779/2019). Consequently, the paper proposes a knowledge management policy design to structurally and holistically address the identified problems. The policy design is tested through an online survey of maintenance engineers in the Dutch railway sector.

The validation presented demonstrates not only the need for a policy design for railway maintenance knowledge management but also the need to pay attention to the human aspect to cope with the continuous changes in the railway sector. It shows that a technology push alone cannot produce the desired results for organisational learning and railway maintenance performance. It also argues that the digitalised processes and knowledge management systems introduced must make the organisation's staff sufficiently sensitive to learning from shared knowledge. By presenting an integrated knowledge policy design that considers learning from assigned maintenance functions (i.e., ECM functions based on VO779/2019), organisational staff's preference for knowledge sharing in inter- and intra-organisational domains, and cultural constraints, this paper provides much-needed clarity for adequate knowledge management for railway maintenance management. Similarly, it encourages a more bottom-up approach to drive key evolutions in the Dutch railway sector by proposing three feedback loops to the organisation's goal and vision.

A key takeaway from the presented knowledge policy design is that there is a need for a common approach to embraceability. By giving knowledge embraceability a principal place in the presented policy, railway organisations can strive to digitise their processes in such a way that they are user-friendly and contribute to the overall learning culture of the organisation. The validation conducted also revealed that providing feedback and enriching organisational goals and vision based on prescribed activities and approach is central to the effective use of the presented knowledge policy. In terms of the necessity and utility of the proposed policy design, the validation showed that it can help reach the low-hanging fruit when it comes to adequately managing maintenance-related knowledge.

In conclusion, by implementing this policy design, railway organisations can ensure that their maintenance-related goals, such as the long-term effectiveness of maintenance plans and

overall maintenance management performance improvements, can be achieved in a timely manner. A key limitation of the proposed policy design is its limited validation. A more thorough validation is needed to increase the generalisability of the results presented. Another limitation is the lack of implementation of the proposed policy design in practice. Future research following this work includes implementing the developed policy design in the Dutch railway sector and analysing its effect on the knowledge management systems used and the learning culture of the organisation. Finally, future research may also consider establishing process models for knowledge sharing that can be implemented in information and knowledge management systems to increase their overall embraceability and utility.

Acknowledgements

This research is co-financed with a PPP surcharge for Research and Innovation from the Dutch Ministry of Economic Affairs and Climate.

Appendix A

Hi colleagues,

….

The idea is to develop a knowledge management policy draft that can address key maintenance management challenges in our department and can be used as a reference to justify and demonstrate some of the ongoing and future developments in our department.

….

I invite you to review the attached policy draft and provide feedback (by responding to this email) on how it can be further improved, for example by providing feedback on the perspectives listed in Table 1:

Table 1. Policy design reviewed on following perspectives.

1.	Indicating which aspects are missing from the policy figure
2.	Whether you think it is necessary to create such a policy design
3.	What maintenance management challenges such a policy could overcome and suitable cases for the application (to test its usefulness).

…..

I would greatly appreciate it if you can send me your feedback before 9 December. Thank you for your continued support. Best regards,

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