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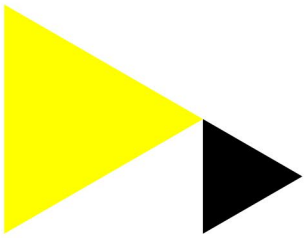

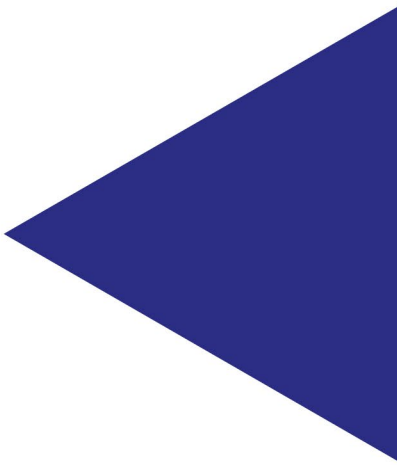

Measuring the clients' maturity in smart maintenance supply networks

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Summary
This paper aims to develop a tool for measuring the clients' maturity in smart maintenance supply networks. The assessment tool is developed and validated for corporate facilities management organizations using case studies and expert consultation. Based on application of the assessment tool in five cases, conclusions are presented about the levels of maturity found and the strengths and limitations of the assessment tool itself. Also, implications for further research are proposed.

Keywords: maintenance, digitalisation, supply networks, maturity
Submission category: academic working paper

Introduction

The combined use of sensor technology, radio frequency identification (RFID) and distributed ledger technologies, can connect physical assets to the internet of things (IoT). The introduction of these new technologies creates opportunities for servitization of assets but also makes maintenance supply networks difficult to manage, partly due to emerging professional expertise, service roles and evolving technologies.

This paper takes the perspective of the client in the maintenance supply network. The client in this research is the maintenance function of a Corporate Facilities Management (CFM) organization of a university. Managing a dynamic and evolving maintenance supply network in the light of increased digitalisation may require the development of capabilities that are new to the maintenance organization. Maturity models are widely used to develop and improve organizational capabilities through the assessment of maturity identified as competency, capability or level of sophistication. In recent years, maturity models have been gaining attention in the field of maintenance management. Through this research, however, we found no evidence for the existence of a maturity model that measures the level of professionalism to what extent the requirements imposed by digitalization of assets in maintenance supply networks are fulfilled.

The purpose of this paper is to design and evaluate a smart maintenance maturity assessment tool that meets the requirements of CFM organizations in addressing the internal and external dependencies in the data supply network. The research is guided by the following research question: *How can a smart maintenance maturity assessment tool*

be developed for CFM organizations that addresses internal and external data supply network dependencies?

The following section summarizes existing maturity frameworks and literature on smart maintenance supply networks. Section three describes the research plan as how the research has been designed in two stages, using case studies and expert consultation. Section four describes the results of implementing the tool through maturity assessments in five cases of corporate facility management organizations of universities. Section five finally contains some conclusions and intentions for future research.

Literature

Smart maintenance literature has been aimed at understanding the impact of industry 4.0, with a particular interest in the use of advanced technologies, data science and predictive analytics (e.g. Bokrantz et al., 2020; Johannes et al., 2021). Bokrantz et al. (2020) define smart maintenance as *'an organizational design for managing maintenance of manufacturing plants in environments with pervasive digital technologies'*. Others have discussed asset digitalization for smart contracting. Smart contracts, in the form of computerized transaction protocols, execute the terms of a maintenance contract for which repetitive maintenance transactions are programmed, coded and embedded into a blockchain in advance.

Murphy & Chang (2009) were among the first who applied a maturity model to what, in hindsight, could be viewed as some form of smart maintenance. Their discussion however is limited to capturing and managing engineering data. Schmiedbauer et al. (2020) present a maturity model for the manufacturing industry that combines smart maintenance with lean management and Papic & Cerovsek (2019) present a maturity framework that describes how organizations can become more mature in working with a digital twin.

It seems that smart maintenance literature is dominated by the manufacturing industry and industrial maintenance. The real estate and facilities management perspective is missing. Such a perspective should take the external service supply network and the internal stakeholder network into account. The maintenance function is situated at the interface of an internal network of stakeholders, and external construction supply- and maintenance supply networks. For this study we define smart maintenance management as the lateral leading of internal and external networks in creating stakeholder value with networked asset data. The second observation with respect to the existing maturity models is that the models of Murphy & Chang (2009), Schmiedbauer et al. (2020) and Papic & Cerovsek (2019) are all theoretically based on the Capability Maturity Model (CMM) and Capability Maturity Model Integration (CMMI) methodology. Another conceptualisation of maturity is discussed by Bemelmans et al. (2012) linking purchasing maturity to value chain integration according to six stages identified by Van Weele (2014). We will follow this approach in operationalising the maturity levels because the six value chain integration stages provide a rich and informative assessment of smart maintenance maturity in its networked environment.

Methodology

In this study, a tool for measuring a clients' maturity in smart maintenance is designed and evaluated. The assessment tool is developed using a two-stage research design (Figure 1). In the first step of the design stage, maturity dimensions were identified by combining a typical and an extreme case. In the second step of the design stage, for all dimensions, level descriptions were developed according to the six stages discussed by Van Weele (2014, p). Because of the institutional similarities between the maintenance

and the purchasing function in corporate environments, this theoretical perspective is expected to generate new insights not only into the maturing of purchasing but on smart maintenance as well. Both purchasing and maintenance are non-core processes that support the core business of an organization. Both operate in a complex internal stakeholder environment and interact with external suppliers and markets. Based on content analysis of Van Weele's purchasing model, the six value chain integration stages (*transactional orientation, commercial orientation, maintenance coordination, internal integration, external integration, value chain integration)* were transferred from the purchasing function towards the maintenance function, retaining the original level characteristics in that process. By linking these stages to the maturity dimensions, the maturity dimensions were operationalised for measurement purposes. For all 23 dimensions, level descriptions were developed in terms of requirements that need to be met for each level. Finally, a questionnaire was developed for the assessment of each dimension.

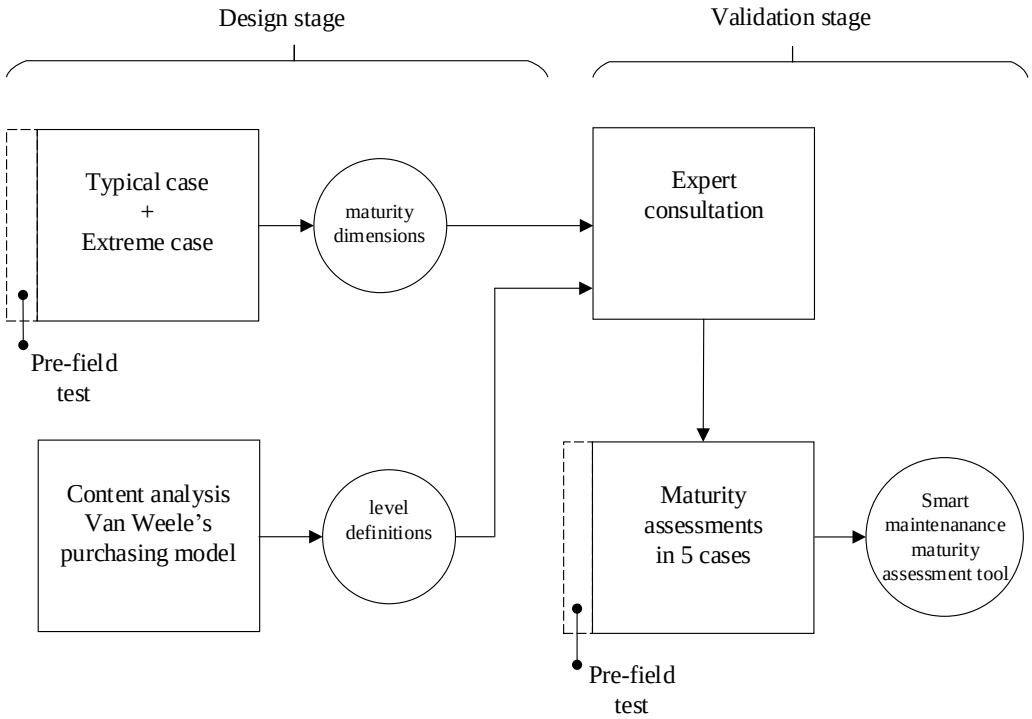

Figure 1 - Research design for developing maturity assessment tool

The assessment tool was validated in two steps. First, the maturity dimensions and level definitions were presented to a panel of seven experts. These experts were selected based on their experience and expertise. Second, the tool was applied in five cases of corporate facility management organizations of universities. A team of multiple investigators performed 22 structured interviews using the questionnaire as the key research instrument.

Results

Table 1 shows the preliminary results of the maturity measurements for the five cases. Further analysis of the data is required in order to fully understand the maturity found in the cases. At first impression, the data suggest that the clients in the investigated cases are less mature in 'Lifecycle modeling', 'Predictive maintenance' and 'Knowledge creation'. The scores recorded on these subdimensions are at the lower end of the maturity scale. This would suggest that in general, the clients' maturity on these subdimensions is

characterized by less integration internally as well as externally. For 'Predictive maintenance' for example, a maturity level of 2 (commercial orientation) implies that clients have a documented method for recording asset criticality, but it is not translated into a predictive maintenance policy, nor is it integrated with the predictive measurement technologies of 1st 2nd and 3rd tier contractors. A score of 5 (external integration) recorded on 'Governance of projects' and 'Governance of outsourced maintenance' on the other hand, means that in those cases, the execution of investment projects and maintenance services is centralized within the client and delivered by a small group of pre-selected contractors.

Table 1 – Data from five maturity assessments

	Case 1	Case 2	Case 3	Case 4	Case 5
Governance of projects	6	3	4	5	5
Governance of outsourced maintenance	6	5	5	5	4
Governance of asset data	4	5	5	5	3
Alignment of processes	5	6	5	5	4
Alignment of data definitions	3	3	4	5	3
Alignment of systems	3	6	3	2	3
Tracking and tracing of assets	3	5	3	4	3
Tracking and tracing of condition	6	3	4	5	5
Tracking and tracing of jobs	5	6	3	6	4
Lifecycle modelling	2	3	4	3	2
Predictive maintenance	2	1	5	2	2
Evidence based contract administration	2	6	5	3	2
Energy performance M&V	4	5	2	4	1
Asset monitoring and replacement	4	4	4	4	4
Project manager support	4	4	3	3	2
Maintenance contractor coaching	2	4	1	5	3
Knowledge creation	3	3	2	4	2
Maintenance needs and requirements	4	3	4	4	4
Handling non-standard asset data	2	6	4	2	3
Valuation of asset data	2	2	4	5	5
Innovation approach	5	6	3	4	4
Safe learning environment	3	5	3	5	3
Collaborative business values and goals	6	5	4	5	4

1 = transactional orientation; 2 = commercial orientation; 3 = coordination
4 = internal integration; 5 = external integration; 6 = value chain integration

Discussion and preliminary conclusions

In a first preliminary analysis of the results, some issues are identified for further elaboration. First, the data of different respondents (clients as well as contractors) confirm the extensive and complex nature of maintenance supply networks. Maintenance supply networks perform interrelated and depending tasks to produce and deliver goods and services to asset owners. They can incorporate both product service supply chains (PSSC) as well as service only supply chains (SOSC) (deSouza & Haddud, 2017). How data supply networks associated with maintenance service supply networks should be framed,

is an interesting topic for future investigation. In particular in the light of human interaction in service delivery processes, which makes precise management and control difficult (Ellram et al., 2004).

Another issue that emerged during the assessments relates to the validation of the tool itself. The tool is designed and validated for corporate facility management organizations of universities. The findings shared by multiple investigators suggest that proper application of the tool requires considerable knowledge of the business context and maintenance supply chains. Further research will be conducted to develop guidelines for application of the tool. The authors will also conduct a second expert consultation on the final results of the five cases, to strengthen the validation of the smart maintenance maturity assessment tool.

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