
4th Conference on Production Systems and Logistics

Literature Review of Process Models in Asset- and Maintenance- Management-Systems

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Abstract

Due to the advancements in digitalization and increasing system complexities during the past decade, asset and maintenance management are becoming more important in companies. Especially in manufacturing companies, lean, effective and efficient production is necessary, which can only be achieved with optimal strategies for physical assets and excellent asset management, to master challenging market situations. System models are supporting management tools for the systematic development of asset and maintenance management in the company. One of the most common types of system models are process models, which are abstract representations of complex processes. They represent the chronological and factual sequence of functions, activities, essential subsystems, properties and interfaces. Numerous process models of maintenance and asset management have been published over the years, representing different objectives and aspects. This article provides a framework that clarifies the morphology of the models mentioned in literature. Finally, the similarities and differences regarding model application in practice and further research are discussed. Overall, the article intends to help researchers derive new, extended and optimized models for the domain.

Keywords

Asset Management; Maintenance Management; Process Models; Framework; Business Management;

1. Introduction

Increasing market dynamics, growing system complexity, shortened technology cycles, and rising competitive pressure are prevalent problems of manufacturing companies. These risks have a significantly strong impact on the physical assets of manufacturing companies, which are supposed to cover a high product portfolio, ensure a high degree of availability and produce high-quality products. To counter these sources of danger and risks in the best possible way and to be able to preserve the market position, dynamic further development across all areas of the company is essential. In this context, maintenance and, more comprehensive, asset management is becoming increasingly crucial as reliability requirements continue to rise. [1,2] The basis for efficient and effective maintenance and asset management is a model for the structure and description of the contents of a management system for the respective company. System models, which are essentially management tools that enable structured implementation, serve this purpose in particular, in this case, for asset and maintenance management. One of the most common types of system models are process models, which are abstract representations of the processes of complex structures. They represent the temporal and factual sequence of functions, activities, essential elements, properties and interfaces. [3,4] Over the past decades, various models have evolved, focusing on different aspects. These range from generic models to specially designed models for specific niche areas. Likewise, the various models differ significantly in the level of detail, which in turn influences the scope of the processes mapped.

The main objective of this paper is to show the existing process models and their contents for the design and development of maintenance and asset management, with their differences, advantages, limitations and characteristics. For this purpose, a literature study was conducted, which screened known literature databases, university theses, and books in this field via internet searches.

2. Models in Asset- and Maintenance-Management-Systems

For further work, it is essential to understand which models were searched for and compared in the literature study. The aim was to specifically address process models that serve to introduce and build a structure in this domain, not to find philosophies or strategies in the field of asset management.

2.1 Process Models

The process model is the graphical, purpose-related and immaterial representation of a temporal and factual sequence of the function carried out on an object to ensure a better overview. [5,4] The goal is to represent complex processes simply and understandably to enhance understanding among the stakeholders as well as communication and to improve the company's success factors - such as cost, time, quality, flexibility, environment and safety. [6] The modelling of an enterprise process often turns out to be complex because the purpose of the process model can be lost sight of by unstructured proceedings. Process models are used in companies for a wide variety of purposes. Starting with the mapping and analysis of operational processes up to the use in projects for management system certifications. When creating these, it is essential to follow a structured procedure, such as the procedure from the project perspective, the procedure from the perspective of the process hierarchy, or the procedure from the perspective of the process dimensions.

2.2 Process Models in Asset- and Maintenance Management

In the domain of asset and maintenance management, process models can depict the holistic activities on the three different management levels.

The normative level deals with corporate policy, corporate goals, corporate constitution and corporate culture. To create benefits for the respective target groups define At this level, the principles, norms and rules for ensuring the company's viability and development. [7] The starting point is the corporate vision, which defines the corporate actions and forms the basis of the corporate policy and the corporate mission for the corporate development derived from it. It thereby creates legitimacy for the actions at the strategic level. [8,9]

Strategic management focuses on the creation, preservation and utilization of success potentials, for which resources must be used. [8] The main task of this level is the design of organizational structures and management systems, the design of relevant programs, as well as the problem-solving behaviour of the company's actors. The goal of strategic management is to influence the activities set and to perform actions in accordance with the defined policy, as well as to ensure the company's long-term future. [9,7]

The strategic management is implemented in the operational actions, which are focused on economic, performance, financial and information processes. Operational management aims to implement the targets defined at the strategic level and measures to achieve the corporate and asset management targets. [9]

A central role in a process model for asset and maintenance management is also given to the management functions with planning, control, information, organization and personnel management [10–12] this ensures a dynamic improvement and an orientation of the management system towards an efficient and effective management. [13] These management functions can also be used from the operational to the normative level.

Planning

The goal-oriented planning forms the main task of a manager and serves the systematic [14], prospective thinking through and definition of goals as well as measures and means for the goal reaching. [15] It also has the coordinating function of steering the corporate processes. [12] The issues that are examined in the course of planning are, on the one hand, the corporate goals (goal planning), the corporate structure (structure and provision planning) and, on the other hand, the planning of the process flows (process planning). All planning processes have in common that they are information processing operations or system design, serve to adapt to environmental changes, take place through a sequence of planning phases, and that planning itself must be planned and is an instrument of coordination which itself must be coordinated. [14]

Control

Control, the counterpart to planning, serves to reduce uncertainties in the planning process. These uncertainties range from checking assumptions and verifying the target effect of planned measures to monitoring the available resources and behaviour of those involved. [14] Thus, the main task consists of target-performance comparisons, evaluation of results, deviation analyses and, if necessary, adaptation of the planning and all other sub-management systems. [16]

Information

Planning and control require information supply. Thus, the goal of information is to provide management with results-oriented information with the necessary degree of accuracy and compression at the right place and at the right time. Important in information is the right balance between the content, the form of the statement and the information properties of the information. [14]

The main requirements for information supply from the point of view of planning and control are making planning problems visible, showing the information about the possibilities of action, and flexible adjustment to the changing environmental conditions. Furthermore, the information supply should be economical, user-adequate, and determined by a structured system with linear tasks. [16]

Organization

The goal-oriented control of operational activities is the primary goal of the organization. Thus, it is also one of the business management tools with the main task of coordination. These coordination activities can reach from the distribution of tasks over the organization of instruction and decision rights up to the organization of spatial-temporal relations of physical processes and information processes. Within the structure and operational organization, it covers this subrange of measures for coordinating tasks and the coordination between the management subsystems. [16]

Personnel management

Personnel management is understood to be that subsystem of management, which is directed at employee management. Thus, it includes the employees themselves, the managers controlling them, and all related instruments and processes. The central tasks of personnel management are recruitment, planning, administration, development, evaluation and controlling of personnel. [17] Since it takes place through social interactions, information plays a crucial role in this context. Planning, control, information and organization relates closely to personnel management, and the associated tasks only become effective through good personnel management. The difference between this and the other leadership subsystems is that personnel management is linked to the participation of the people concerned. The effectiveness of the other leadership subsystems only occurs when the respective output influences the behaviour of the employees, which in turn depends on personnel management. Since the measures of information, planning, control, and organization only become effective through personnel management, coordination among them is very important. [16]

Overall, the process model and its contents intend to support companies in designing and developing comprehensive asset and maintenance management in a structured manner.

3. Research Methodology and delimitations

Bibliographic searches were conducted in the following electronic databases:

- Scopus
- Web of Science

The search function was used to search the two electrical databases for the contents maintenance management, physical asset management, system models, process models, control loops and framework. The restriction also only includes titles from the year 1980 onwards. One thousand and two entries were found in total during the query. After excluding the following criteria, 14 articles remained:

- The article must represent a holistic maintenance management model and not be limited to a specific management area.
- The model presented in the article must be a process model.
- The model must not be a computer model or a computerized maintenance management system (CMMS).

For the papers, the title was screened at the beginning for a first elimination, then an abstract screening of the remaining contents was performed, so that further contents could be eliminated. A full text screening was performed for the remaining publications, finally the mentioned 14 contents remained. In addition to the 14 articles in the electronic databases, a literature search of books and university publications was conducted. In the case of the university publications, the focus was on the German and Austrian regions. Thereby further relevant contents for this literature study could be included. This way, 26 contributions were selected, representing the process models for asset and maintenance management. The further article will detail which levels and aspects of the management functions are included in the individual models.

4. Results of content analysis

Table 1. present the found 26 contributions. In the first step, the selected contributions were examined to determine which levels - normative, strategic and operational - are dealt with in the process model. A more detailed description of the individual levels can be found in Chapter 2 Process Models in Asset and Maintenance Management Systems. At the outset, it can be seen that the normative level is the least addressed in the literature and is rarely formulated. In the standards, the normative level is mentioned only very superficially [18–21], whereas in BIEDERMANN and FERNÁNDEZ, for example, this level is described in detail, since it has an influence on the overall design of the management system [22,23]. Most process models, almost all of them, focus on the strategic aspect and are mainly concerned with the choice of strategy. It is clear that the more recent contributions include predictive maintenance as a strategy choice, or that data analysis models are in use, reflecting the technological progress in maintenance. [24,25] Also the operational level is considered to a quite small extent; the level itself is cited in more than half of the contributions, but a more detailed elaboration of the operational activities rarely occurs.

Table 1: Process Models in Asset- and Maintenance Management

Nr. [Source]	Author	Title	Year	Normative Level	Strategic Level	Operational Level	Planning	Information	Organization	Control	Personnel Mgmt.
1 [26]	da Silva, R. F.; Souza, G.F.M. de	Modeling a maintenance management framework for asset management based on ISO 55000 series guidelines	2021		•	•	•			•	
2 [27]	Hassanain, M. A.; Froese, T. M.; Vanier, D. J.	Framework model for asset maintenance management	2003		•	•	•	•	•	•	
3 [25]	Linneusson, Gary; Ng, Amos H. C.; Aslam, Tehseen	A hybrid simulation-based optimization framework supporting strategic maintenance development to improve production performance	2020		•	•	•				
4 [28]	Marquez, A. C.; Gupta, J. N.D.	Contemporary maintenance management: process, framework and supporting pillars	2006		•	•	•	•	•		
5 [29]	Márquez, A. C.; León, P. M. de; Fernández, J.F.G.	The maintenance management framework: A practical view to maintenance management	2009		•		•	•	•	•	
6 [30]	Biedermann H.	Organisation zur Realisierung der Instandhaltungsplanung.	1987	•	•	•	•		•		
7 [31]	Kinz A.	Ausgestaltung einer dynamische, lern- und wertschöpfungsorientierten Instandhaltung	2017	•	•	•	•	•	•	•	•
8 [22]	Biedermann H.; Kinz A.	Lean Smart Maintenance	2021	•	•	•	•	•	•	•	•
9 [18]	Austrian Standards Institute	Instandhaltungsprozess und verbundene Leistungskennzahlen - EN17007	2017	•	•	•	•	•	•	•	
10 [19–21]	International Organization for Standardization	Asset management - ISO 55000 Reihe	2014	•	•		•	•	•	•	
11 [32]	Campbell JD	Outsourcing in maintenance management: A valid alternative to selfprovision	1995		•	•	•		•		
12 [33]	Vanneste SG, Van Wassenhove LN	An integrated and structured approach to improve maintenance	1995			•	•			•	
13 [34]	Riis J, Luxhoj J, Thorsteinsson	A situational maintenance model	1997	•	•		•	•	•	•	

14 [35]	Wireman T	Developing performance indicators for managing maintenance	1998		•		•		•			
15 [36]	Duffuaa SO, Raouf A	Planning and control of maintenance systems	2015	•	•		•	•	•	•	•	•
16 [37]	Tsang A	Strategic dimensions of maintenance management	2002		•		•				•	•
17 [38]	Waeyenbergh G, Pintelon L	A framework for maintenance concept development	2002		•		•	•			•	
18 [39]	Murthy DNP, Atrens A, Eccleston JA	Strategic maintenance management	2002		•		•					
19 [40]	Abudayyeh O, Khan T, Yehia S, Randolph D	The design and implementation of a maintenance information model for rural municipalities	2005				•	•	•	•	•	
20 [41]	Pramod VR, Devadasan SR,	Integrating TPM and QFD for improving quality in maintenance engineering	2006		•		•			•	•	
21 [42]	Kelly A	Strategic maintenance planning	2007	•	•	•	•	•	•	•	•	
22 [43]	Söderholm P, Holmgren M,	A process view of maintenance and its stakeholders	2007	•	•	•	•	•	•	•	•	
23 [23]	Fernández, J.F.G.; Márquez, A. C.	Defining maintenance management framework	2012	•	•	•	•	•	•	•	•	•
24 [44]	Campos, M. A. López; Márquez, A. Crespo	Modelling a maintenance management framework based on PAS 55 standard	2011	•	•		•	•	•	•	•	•
25 [24]	Galesi-Torres, A.; Velarde-Cabrera, A.	Maintenance Management Model under the TPM approach to Reduce Machine Breakdowns in Peruvian Giant Squid Processing SMEs	2020				•	•		•	•	
26 [45]	Palomino-Valles, A.; Tokumori-Wong, M.	TPM Maintenance Management Model Focused on Reliability that Enables the Increase of the Availability of Heavy Equipment in the Construction Sector	2020		•	•	•				•	
Sum				11	23	16	26	15	19	20	6	

The five major management functions, planning, control, information, organization and personnel management, are addressed for further analysis of the various contributions. This involved examining which functions are covered in each model. The focus of the process models is on planning, which can be explained by the increased consideration of the strategic level. One of the main tasks of process models is to support planning tasks in order to ensure structured planning, which explains why the planning function is addressed in every process model listed. Especially the planning for the maintenance strategies to be used is presented in the papers. In addition, administrative planning activities are often identified in the process models as well.

The information function was observed in terms of the functions and activities between which the information structure is built and which information is to be communicated. About half of the contributions

represent the information structure in the process model, or they show how the functions interact with each other and thus represent an information interface.

Some contributions deal with the organizational function in their description and illustration of the process models by showing the structure of the asset and maintenance organization. Based on the organizational structure's representation, the employees' functions are likewise mapped directly in the process model. This allows for a direct transition to personnel management, but only at a few contributions.

In the case of the control function, almost all contributions depict a controlling cycle. Either about PDCA or simple control loops to be able to control the management system. In terms of content, most process models describe the controlling function only marginally and hardly show a viable approach for implementation in companies. The detailed processes in the model themselves are hardly ever depicted in control cycles, or no control function is shown. This means that the quality aspect of the individual mapped processes is hardly present.

Despite the good representation of the organization and its functions, only a few contributions describe the direct influence of the co-workers on the management system. In some cases, human resources are described and perceived as necessary. Still, there is no focus on how to deal with employees or how personnel can be used to be able to cope with the diverse activities in a holistic asset and maintenance management.

5. Conclusion

In summary, it can be said that the existing process models in the area of asset and maintenance management primarily deal with strategic conditions, whereby the focus here is on the choice of strategy for the individual assets in the enterprise. Thus, the operational level and executive activities are included in most process models, but these activities are hardly ever dealt with or described in more detail. This follows from the fact that the activities of the operational employees in the different branches can be very heterogeneous. The normative level is barely considered in the previous process models, i.e. philosophies, missions or visions of the maintenance organization are rarely considered. Accordingly, the target system cannot be aligned with an adapted vision.

Most of the articles found, show that a maintenance management system is depicted as a process model since the four basic maintenance points are usually addressed. Especially the more current contributions describe an holistic asset management. A trend towards asset management is also visible in the process models. The expanded view of assets over the entire life cycle and more significant consideration of interdisciplinary topics are being examined in increasing detail and thus show the significant influence that asset management has on the entire company.

The focus on the management functions is clearly on planning, which is also described across all levels. The information and organization function influence themselves strongly since, by the illustration of the organization, the information structure can already be indicated. Mostly here, the paths and interfaces of the information are pointed out, and the contents are rarely dealt with. This is reflected in the control function again since a control loop for the improvement and illustration of key figures is given. However, hardly the more exact processes are dealt with, whereby direct controlling of the processes becomes difficult. As a result, the quality control of the actual execution of the processes is merely described on the surface, and companies see a need to catch up with a model that supports the quality of the maintenance activities and generally of the processes to be able to monitor and control them. Personnel management is also neglected in the process models; it is only presented as an important human resource, and the comprehensive functions of this topic are severely overlooked. This presentation of the process models is intended to support the user in finding the right model for his area, and also to show alternatives.

It is easy to see that the process models have evolved considerably over the years, especially in the concept of asset management, which makes the scope of consideration even more extensive. A need for research is seen in the area of the normative level, as well as in the function of personnel management and control. Particular attention should be paid to the quality control of the individual processes, making the processes more controllable and hence improving the efficiency of asset and maintenance management.

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