ASSESSING MAINTENANCE MANAGEMENT IT ON THE BASIS OF IT MATURITY

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Research shows that investments in IT have a positive correlation to company profitability and competitiveness. This is the case also for maintenance management IT (MMIT), i.e. applications used for maintenance management purposes such as computerised maintenance management systems (CMMS) and maintenance management or asset management modules in enterprise resource planning (ERP) systems. Although, models and methods for evaluating maintenance IT needs and IT systems are not well developed. This paper shows how the IT maturity of the maintenance organisation could be considered in the IT procurement process. If we are able to define functionality for different levels of IT maturity, the assessment and selection of the relatively best IT application for the maintenance organisation would be supported. A model describing three phases of IT maturity within maintenance (IT beginners, medium IT users and IT mature organisations) forms the theoretical basis. The applicability of the approach is tested by evaluating 24 CMMS and enterprise resource planning (ERP) systems.

Key Words: Computerised maintenance management, maintenance IT functionality, IT maturity

1 INTRODUCTION

To reach success in the utilisation of information technology (IT) for maintenance management, we must be able to choose the relatively best alternative from a set of possible IT solutions. This requires an ability to understand the maintenance IT needs, as well as ways to assess different alternative IT solutions. Although Computerised Maintenance Management Systems (CMMS) have been in use for several decades, models and methods for evaluating maintenance IT needs are not well developed.

This paper will address how the maintenance management information technology (MMIT) procurement process could be supported by taking into account the IT maturity of the maintenance organisation. IT maturity denotes the extent to which an organisation or a human can benefit from the technology [1]. If we are able to define functionality for different levels of IT maturity, the assessment and selection of the relatively best IT application for the maintenance organisation would be supported. A model for determining the IT maturity of maintenance was developed in [2] and validated in [3]. In this paper, this model will be used as a basis for defining IT functionality requirements for the evaluation of different MMIT systems alternatives.

2 METHODS SUPPORTING THE PROCUREMENT OF MMIT

For covering the past research within the assessment of MMIT, a literature survey was conducted in the full text database ELIN (Electronic Library Information Navigator), which integrates vast amount of databases and providers, such as Blackwell, Cambridge journals, Emerald, IEEE, Science Direct and Wiley. Key words were chosen to cover the area of computerised maintenance management combined with the terms benefits, needs, requirements, purchasing, procurement, selection and evaluation. 40 hits in all were addressing MMIT, representing 22 unique papers published between 1987 and 2008.

Three papers were found which address the problem area of MMIT procurement, especially focusing on identifying and selecting IT systems. The first, [4], presents an evaluation model based on multi-criteria decision-making (MCDM) and the analytic hierarchy process (AHP). The model comprises seven levels, where level two is different scenario alternatives classifying future users of CMMS. This classification is mainly based on maintenance organisation size, but also on maintenance practices and technology utilisation. Levels three to six represents the criteria to be considered, in all 52 criteria. Four generic CMMS alternatives are represented in the seventh level. By utilising this model, the needs of the company,

identified as belonging in one of the scenarios, could be connected to one generic CMMS alternative and thereby reduce the decision complexity, before the selection of software application alternatives is made.

This model is similar to the work of [5] that also proposes an MCDM/AHP approach for the evaluation of CMMS. This model consists of five levels, wherefrom four represents the criteria for evaluation based on the ISO-IEC 9126 classification. The CMMS alternatives are classified according to size characteristics, while the needs are exemplified by judgements from administration, production and maintenance in paper industries.

These two publications provide well structured and objective methods for evaluating CMMS, and the MCDM process is commonly used in the software selection process, providing possibility to compare different alternatives with respect to large amount of criteria. The MCDM is a tedious process and requires much data and ability to process the data appropriately though. Thus, developing criteria for the MCDM requires a lot of effort, and it is hard to align the criteria with the demands of the organisation. Moreover, the criteria selected for analysis in [4] and [5] are mainly non-functional requirements.

In the third paper, [6], a method for determining IT requirements in maintenance was developed, which could be useful in the requirements determination and CMMS selection. It does not address any specific methods for the actual selection though, such as in [4] and [5]. It is suggested in [6] that IT maturity plays a role in the IT requirements determination process. Therefore, determining the IT maturity of the organisation is in [6] one step in defining the current state of the maintenance. IT maturity could be one way to reduce decision complexity in a MCDM analysis if it is used to classify IT solutions, and thereby reduce the amount of candidate IT systems to consider in the further analysis process.

3 IT MATURITY OF MAINTENANCE

IT maturity denotes the extent to which an organisation or a human can benefit from the technology. An organisation with a low level of IT maturity uses IT mainly for the automation of daily activities and for data storage, while an IT mature organisation uses IT for collecting and combining vast amount of data for advanced strategic decision making [7]. This section will discuss the term IT maturity with respect to maintenance management.

3.1 The Maintenance IT Maturity Model

A model for determining information technology maturity within maintenance, which is an application of the IT maturity and growth model by Nolan [7], was developed in [2] for the positioning of the maintenance organisation relative to its IT maturity. The model was validated in a study presented in [3]. Three distinct groups of companies with different levels of IT maturity were found in the study by the means of cluster analysis. The groups and their characteristics are accounted for in Table 1 in the next section.

In the maintenance IT maturity model three main phases of maintenance IT maturity have been defined: Introduction, Coordination and Integration. The history of industrial computerisation shows that these phases are natural steps towards an integrated IT solution, see [8]. The author also shows that the development of maintenance management IT in general has followed the development of industrial IT. The demands on MMIT has shifted over the years from being a tool to automate preventive maintenance management, such as task scheduling, plant inventory and stock control or cost and budgeting, to support predictive and proactive maintenance by providing real time data processing, effective communication channels and business function integration [9], [10]. The three phases of IT maturity are described briefly as:

1) Introduction (Efficiency reached by using IT): IT is introduced into the maintenance organisation in form of traditional CMMS, which support mainly reactive and preventive maintenance. The procurement of IT is mainly technology-oriented and IT is used for operational purposes. Goals with the IT use are mainly concerning an efficient management of work orders, spare parts inventory, purchase and cost control. It results in good control of available resources and cost reduction of carried out maintenance.

2) Coordination (Effectiveness reached by using IT): Maintenance IT systems and other corporate IT systems are coordinated and the use of IT is more stressed than the technology itself. These more advanced CMMS and ERP systems support mainly preventive, and to some extent, predictive strategies. IT is used for operational and tactical purposes, such as the follow up of carried out activities and failure frequencies. Schedules can be optimised. It results in good control of, and the capability to use, resources in the best way, and investment in maintenance will likely give positive returns.

3) Integration (Cost-effectiveness reached by using IT): Maintenance is an integrated part of the corporate IT system, enabling predictive and proactive maintenance strategies. Investments in IT are connected to actual needs. IT is used for operational, tactical and strategic purposes. Automatic monitoring of damage development and rapid rescheduling of activities is enabled. Based on failure history measures can be judged and the best maintenance alternative can be chosen, giving highest returns of investments.

3.2 IT Systems Functionality Connected to IT Maturity

The IT maturity model could serve as an input for developing appropriate benchmarks for different levels of IT maturity within maintenance. It could also be a tool used by the procurer of MMIT to understand the prerequisites of the organisation before assessing different MMIT solutions available. As such, knowing what functionality to utilise depending on the level of maturity is important. In [6], the IT utilisation within maintenance management was studied with respect to Swedish industry. Table 1 lists the functionality studied and the results of the cluster analysis. Of 71 companies in total, 19 were characterised as belonging to group Introduction, 35 as belonging to group Coordination, and 19 as belonging to group Integration. The type of functions and the extent to which these are utilised is accounted for in the three rightmost columns.

In the Introduction phase Preventive Maintenance planning and scheduling, Work order planning and scheduling, Equipment parts list and Equipment repair history were utilised. These form the core functionality for the first phase. In the Coordination phase following additional functionality were added: Inventory control, Spare parts purchasing, Maintenance budgeting and Key performance measures. For the Integration phase, three more functionalities were included: Equipment failure diagnosis, Manpower planning and scheduling, Condition monitoring parameter analysis and Spare parts requirement planning.

Table 1

Utilisation of IT in Swedish industry, Kans and Ingwald (2008)

Function	Introduction (17)	Coordination (35)	Integration (19)
WO planning and scheduling	2	3	4
Equipment parts list	2	3	4
Inventory control	0	3	4
PM planning and scheduling	4	4	5
Spare parts requirements planning	1	3	4
Equipment failure diagnosis	1	1	3
Equipment repair history	2	3	4
Spare parts purchasing	0	4	4
Manpower planning and scheduling	0	1	3
Maintenance budgeting	1	2	3
CM parameter analysis	1	1	3
Key performance measures	1	2	4

0 = Do not have this functionality, 1 = Used minimally, 5 = Used extensively

4 SELECTING MMIT BASED ON IT MATURITY

This section will illustrate how the maintenance IT maturity could be utilised as a means to compare different MMIT, for instance when selecting which IT system to further investigate for instance by the means of MCDM in a MMIT procurement situation. We will look at two different scenarios depending on the level of IT maturity of the organisation:

- 1) The procurement of MMIT is made for the first time, i.e. computerisation of manual routines. This scenario is characterised by a maturity level corresponding to the Introduction phase.
- 2) The procurement of MMIT is mainly an upgrade from simple computerised support, for instance an obsolete CMMS or a simple spreadsheet solution, to a standard CMMS or ERP system. This scenario is characterised by a maturity level corresponding to the Coordination phase.

A third scenario not addressed in this paper would be the procurement of MMIT connected to a major investment in IT support due to highly automated or complex production. This scenario is characterised by a maturity level corresponding to the Integration phase, and in general these kinds of investments involves the procurement of more IT systems than only MMIT.

4.1 Sample of MMIT Systems to be Evaluated in the Scenarios

A study of commercial MMIT systems' functionality conducted by the author is utilised as a real-world illustration of the problem area of selecting appropriate MMIT. The study covered seventeen CMMS and seven ERP systems that included a maintenance or asset management module, in total 24 IT systems. The basis for the data collection was information from the constructors or vendors of the IT systems in form of folders, brochures, demonstrations, web pages, demonstration software and telephone contact with vendors. Some results connected to this data set were presented in [1]. The information was collected during 2004-2005. The aim was to study the most commonly used off-the-shelf systems used for maintenance management in Swedish industry. The study objects were therefore determined using three sources:

- 1) A survey about maintenance management including 118 Swedish companies conducted by the Department of Terotechnology at Växjö University in 2004, see [11]. In the questionnaire one question covered which commercial CMMS the company used for maintenance management. A total of 87 answers were given. Some companies used more than one system. From these, systems that were used by two or more companies were chosen, in all thirteen systems (10 CMMS and 3 ERP systems).
- 2) An Internet survey of Enterprise Resource Planning (ERP) systems used in Sweden based upon information provided by Data Research DPU AB [12]. Of 100 ERP systems, only seven contained a maintenance or asset management module. These systems were all included in the study (3 of the systems were already included based on paragraph 1).
- 3) A list of commonly used maintenance IT systems provided by Swedish Center for Maintenance Management (Underhållsföretagen) published in [13]. The list contained twenty-one CMMS/ERP systems from where systems that were pure decision support systems or had less than 30 total users worldwide were excluded. The list of study objects was complemented with additional seven systems using this source.

This data set is highly suitable as they represent a real-life decision to be made, and the two latter sources of information could directly be utilised for this purpose. The first source represents the actual choice procurers of MMIT in Swedish industry have made.

4.2 Functionality Selected for Comparison

The functionality included in the survey accounted for in Table 1 did not completely match the functionality included in the study described in 4.1. Therefore a complete mapping of functionality for each IT maturity phase was not possible. The functionality Spare parts requirement planning connected to the Integration phase is therefore not considered. Table 2 lists the functionality that will be considered for each IT maturity phase.

Table 2

IT functionality needs for different phases of IT maturity

IT maturity	IT systems functionality
Introduction	Work order planning and scheduling
	Preventive maintenance planning and scheduling
	Equipment parts list
	Equipment repair history
Coordination	<i>In addition to the functionality connected to phase 1:</i>
	Inventory control
	Spare parts purchasing
	Maintenance budgeting
	Key performance measures
Integration	<i>In addition to the functionality connected to phase 2:</i>
	Equipment failure diagnosis
	Manpower planning and scheduling
	Condition monitoring parameter analysis

5 ANALYSIS AND RESULTS

In the following, the 24 IT systems will be evaluated with respect to their ability to provide the maintenance organisation with IT support depending on IT maturity level and decision-making scenario. The aim is to reduce the number of possible candidates from 24 to around five before a further in-depth evaluation. The functionality coverage for the system alternatives is found in Figure 1 and 2. Figure 1 describes the functionality coverage of CMMS while Figure 2 describes functionality coverage for ERP systems.

The total amount of functions is given for each phase in the legend. For the Introduction phase, we can see that all CMMS contain three or four out of four functions in total. For the Coordination phase the amount of functions varies between four and eight out of eight in total. For the Integration phase the coverage is between four and ten out of eleven functions.

Figure 1. Functionality coverage for CMMS.

Figure 2. Functionality coverage for ERP systems.

Figure 2 is read the similar way as Figure 1. The total number of functions connected to a certain phase is found in the legend. The functionality coverage for the Introduction phase varies between two and four out of four in total for the ERP systems. For the Coordination phase the amount of functions varies between three and eight out of eight in total. For the Integration phase the coverage is between four and eleven out of eleven functions.

5.1 Computerisation of Manual Routines

The decision is to find the most suitable candidates for a maintenance organisation that today relies on manual work. The four functions connected to the Introduction phase are considered as important, and should be mandatory in the requirements specification. The four functions belonging to the next phase will be desirable, while the functions connected to the Integration phase are seen as undesirable, as they indicate a too complex solution for the level of maturity.

From Figure 1 we find nine CMMS reaching the mandatory requirements: CMMS_1, CMMS_9- 13 and CMMS_15-17. These are the candidates to select from. To further delimit the amount of candidates we compare the functionality coverage for the desirable requirements. It is found that four out of the nine CMMS's contains high level of coverage. Therefore, we select systems CMMS_1, CMMS_12, CMMS_13 and CMMS_14 for further evaluation. We note that the system 13 seems to be a highly complex one though and we might disregard CMMS_13 due to this reason.

The ERP system is in general a bit too complex for an IT beginner, but depending on factors such as the existence of an ERP system within the company, this option could be of interest also in this scenario. Four ERP systems contain full coverage of the mandatory functions (ERP_1-3, ERP_6), and these also shows up high coverage for the desirable functions. All of these systems seem to be rather advanced though, and due to this we will likely not go further with them in the analysis.

5.2 Upgrading of Existing IT System

This scenario regards the upgrading of an old, incomplete or simple IT solution for maintenance management. It is assumed that the maintenance organisation as well as the maintenance personnel is IT mature to some extent. They are for instance used to store data in digital form and to plan activities with computerised support. Functions connected to the first and second maturity phase are therefore to be seen as mandatory, while the functions connected to the last phase are desirable. Both a CMMS and an ERP solution are of interest.

Only one CMMS (CMMS_13) and two ERP systems (ERP_1-2) fulfil the mandatory requirements and will be selected for further analysis. However, the system ERP_3 seems to contain a high degree of functions in total and is therefore included in the list of candidates.

6 CONCLUSIONS

This paper proposes taking IT maturity into account in the procurement of IT in maintenance management. In this paper, IT maturity has been used as a means to compare functionality in different MMIT in order to select the most suitable candidate systems for more detailed analysis. As such, it could for instance be utilised as a first step for further MCDM analysis. This paper only addresses the functional requirements, whereas the non-functional requirements have to be considered in the detailed analysis.

The IT maturity is not a static condition. The history of IT has shown how companies gradually have moved from lower to higher levels of IT maturity, resulting in shifting demands on IT applications to be able to meet more advanced business goals. In maintenance, the similar has been noted. This implies that the assessment of IT applications is not an activity to be carried out only when new software is to be purchased, but should be made on regular basis to determine whether the IT is supporting current maintenance practices to full extent or not. For this purpose, the IT maturity model could be serving as a simple yet powerful tool. This paper has shown that the different maturity phases could be translated into IT functionality, which would enable the assessment of IT support on both overall and detailed level.

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