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IT Practices within Maintenance from a Systems Perspective

- Study of IT Utilisation within Firms in Sweden

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1. INTRODUCTION

Maintenance is defined as the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function. Maintenance management is regarded as all activities of the management such as maintenance planning, maintenance control and supervision, improvement of methods in the organisation including economical aspects, SIS (2001). Information technology (IT) systems for maintenance management, hereafter denoted as Maintenance Management IT (MMIT), have existed for several decades. The demands on MMIT has shifted from being a tool to automate corrective and preventive maintenance management, such as task scheduling, plant inventory and stock control, to become support for predictive and proactive-predictive maintenance by providing real time data processing, effective communication channels and business function integration, Pintelon, Preez and Van Puyvelde (1999). Emerging technologies such as web services and open source software are also rapidly adopted in MMIT solutions based on new business logics such as Service Oriented Architecture (SOA) and Software as a Service (SaaS). These solutions, commonly referred to as eMaintenance, spans from traditional maintenance management software capabilities enabled through the web to advanced expert

systems for diagnostics and prediction of future component state. But is industry ready to adopt the novel solutions?

For answering this question, we need to apply a holistic perspective on IT utilisation. IT is technology, but without people using it and a clearly formulated purpose of the use, the technology utilisation as such will fail. Moreover, technology must be managed, maintained and connected to the corporate strategy. A systems approach applied to IT will ensure that the most relevant aspects are captured when studying IT utilisation. Several studies of IT utilisation in maintenance have been performed with the limitation of focusing on one single aspect, such as new applications development in Fernandez et al. (2003), Lee et al. (2006), Muller, Suhner and Iung (2008) and Al-Najjar (2010) or the impact of IT in Mjema and Mweta (2003), O'Donoghue and Prendergast (2004) and White (2004). Some studies include IT support as one factor when studying overall maintenance practices, see e.g. Jonsson (2000) or Buys and Nkado (2006). Other studies, such as in Jones and Collis (1996), Swanson (1997) and O'Hanlon (2008), account for utilised IT support and the level of computerisation.

The purpose of the paper is to describe current IT practices within maintenance in Swedish firms from a holistic systems perspective. This will help us to understand the utilisation of IT within maintenance today, the possible challenges in applying new technology, and to find the opportunities that the current practices bring. The paper disposition is as follows: The next section describes IT practices from a holistic systems perspective. The holistic approach is applied in a study regarding MMIT utilisation presented in sections three and

four. The results are summarised and discussed in section five and conclusions are drawn in the last section.

2. IT PRACTICES – A SOCIO-TECHNICAL SYSTEMS PERSPECTIVE

It is easy to perceive IT as merely technology, but the technical perspective is only one of several perspectives to apply to be able to reach true utility of IT. The goals and purposes of applying IT, the intended use, as well as the characteristics of the users are examples of additional factors to be addressed, Kans (2008). In the following, IT utilisation will be explained from a socio-technical perspective.

2.1 IT systems from a socio-technical systems perspective

Three subsystems comprise the socio-technical system: the human activity system (HAS), the information system (IS) and the information technology system (ITS), Beynon-Davies (2002). Figure 1 depicts these subsystems. The HAS consists of people performing a collection of activities and is synonymous to the term business process. The IS supports the HAS with information processing; as such it is a system of communication between people. Communication is enabled by technology represented as the ITS. The IT system provides required functionality to the organisation while the information system (IS) provides usability in form of a system that is easy to use and learn. The human activity system is connected to the utility, i.e. what benefits the organisation could reach by applying IT.

DeLone and McLean (1992) noted that if information systems research is to make a practical contribution well-defined outcome measures are essential. The available research was summarised in a model comprising six categories of success: system quality, information quality, system use, user satisfaction, individual impacts and organisational impacts. The model was later extended with system support quality; see DeLone and McLean (2003). In the IT system layer, system, support and information quality are important. Without high quality input, you cannot expect high quality output either. In the information system layer the intended use and the actual use are addressed. The use is strongly connected to the user satisfaction. High quality in this layer is characterised by a well designed, intuitive and efficient user interface. Success in the third layer is measured by the impact on the individual user and the organisation as a whole, expressed as the net benefits for the organisation.

Figure 1. The socio-technical perspective of IT systems

There are several systems-external factors that affect the success of the IT systems as well. To begin with, the IT system is connected to various organisational support functions such as the IT strategy, the IT organisation and IT governance strategies, the training possibilities available, as well as technology support in form of operations and maintenance of the IT system itself. The ability to utilise IT is moreover connected to maturity issues. The technology utilised in the organisation in form of platforms and architectures, i.e. technical maturity, the individual users' IT maturity and ability to learn as well as the maturity of the organisation where the IT is applied could affect the success, see e.g. Nolan (1979) and Kans (2008). In the following, the socio-technical system is described with the basis in the three layers.

2.1.1 The technical aspects of IT systems

An IT system could be described as “an organised collection of hardware, software, data and communications technology designed to support aspects of some information system”, Benyon-Davies (2009 p. 5). The IT systems interact with each other and with the external surroundings in different setups called architectures.

The IT system includes logic for storage, processing and presentation, and the distribution of this logic is connected to the architecture. One-tier solutions provides all logic at the same location, for instance as a stand-alone computer or a mainframe. Two-tier solutions normally distribute the logic using the client-server model either as fat clients (presentation

and processing is made at the client) or thin client solutions (only presentation logic is implemented at the client). In three-tier solutions the storage, processing and presentation are separated in a database server, application server, and clients respectively, Hoffer, Prescott and McFadden (2005). Today, the n-tier solutions are emerging, where especially the processing logic is distributed over several servers by the use of web technology.

2.1.2 The socio-technical aspects of IT systems

This layer plays an important part because it connects the individual users with the technology. Achieving the intended use of an IT system is highly dependent on the individual users' ability and willingness to utilise the system. A well designed intuitive and efficient user interface will enable high usability for individual users. Moreover, support in form of a well-functioning IS organisation, training and education possibilities and well defined IT governance strategies are required. The IS organisation should for instance develop, maintain and operate systems, manage supplier relationships, establish platforms and standards, promote security and plan business contingency, Pearlson and Saunders (2009). In practice, this could be achieved either in-house or by third party providers. The importance of appropriate training is highlighted in Chand et al. (2005), where the standard vendor-developed training program was replaced with a context-specific training course, which resulted in faster user adaption to the specific solution.

IT governance is defined by Weill and Ross (2004) as the framework for decision rights and accountabilities to encourage desirable behaviour in the use of IT. In other words, it is about who is making the decisions. Weill and Ross propose five categories of key decisions:

1. IT principles: defining how IT is used in the business
2. IT architecture: defining integration and standardisation principles
3. IT infrastructure strategies: defining strategies for handling IT resources
4. Business application needs: specifying the business application needs
5. IT investments and prioritisations: choosing investment projects

The IT governance strategy describes how the IS organisation and decision abilities are distributed. Centralised IT governance collects decisions to a central IT organisation body while in a decentralised IT governance form, the authority is found in the individual business units, Jacobson (2004).

2.1.3 The social aspects of IT systems

In 1993 Brynjolfsson coined the expression “productivity paradox”; i.e. that IT is not adding to the productivity of a company. His research has later on been both confirmed, see e.g. Theodorou and Florou (2008), and rejected such as in and Ross and Ernstberger (2006). Reason behind inconsistent results are for example difficulties in finding appropriate measures to study the impact of IT investments and the time lag problem, suggesting that the impacts of investments in IT could not be seen until years later, Byrd et al. (2006).

Several methods for assessing impact have been developed trying to capture both financial and non-financial impacts. Shang and Seddon (2002) for instance developed a framework for enterprise system benefits comprising operational, managerial, strategic, IT infrastructure and organisational aspects while Chand et al. (2005) applied a balanced scorecard approach which measures impact on the dimensions process, customer, finance

and innovation. The business case approach by Ward et al. (2008) classifies the impact into four measurement levels, from the intangible observable benefits to the highly tangible financial benefits.

2.1.4 Interactions between different layers

Hackbarth and Kettinger (2004) as well as Nolan (1979) describe the IT growth as a shift in focus from technology-driven IT investments to IT investments driven by business needs. When introducing IT into an organisation the investment decision tend to focus on technical aspects rather than the way IT will be used. An IT mature organisation is characterised by IT investment decisions connected to actual organisational needs rather than what to procure and how it will be utilised. The IT mature organisation could utilise IT as a means to create business opportunities. From a historical perspective, amongst the first advantage of enterprise IT was the automating of information processing and existing routines leading to cost reductions, Dahlbom (1997). Continuously, customer orientation and globalisation required well functioning vertical as well as horizontal information flows, Holland and Light (1999).

The evolution of business from function/vertical oriented through process/horizontal oriented to the network/eco systems oriented has been in parallel with the evolution of IT and the IT architecture, IBM (2004), see Figure 2. The one-tier solutions mainly supply vertical, function-specific IT support, while two- and three-tier solutions give the possibility for cross-functional information sharing, as well as meeting the function specific needs. N-tier and service oriented solutions does not only enable intra-corporate, but also inter-

corporate information supply throughout the full supply chain, from raw material supplier to end customer. Two of the common service oriented concepts are Service oriented architecture (SOA) and Software as a Service (SaaS).

Figure 2. Evolution of business and IT architecture

SOA is a framework for integrated services in a distributed environment, where software and hardware communicates through common standardised interfaces. SOA consists of policies, practices, frameworks and technology in order to provide the right services for the business, Spratt and Wilkes (2004). The main goals of SOA are according to Bygstad and Gronli (2011) to address challenges of how the IT architecture could support organisational innovation and agility, for instance in terms of flexibility, efficiency and reuse. SaaS refers to the way services are distributed and accessed. SaaS applications are hosted, supplied and accessed by users over the internet from third part suppliers. Ju et al. (2011) refers the price of SaaS as an “all in” monthly subscription fee which replaces the usual cost for e.g. software licences, maintenance and support.

2.2 IT practices in maintenance

The theoretical discussion will end with a brief overview of IT practices as described in previous research.

2.2.1 Information technology applications for maintenance management

The Computerised Maintenance Management Systems (CMMS), with some 50 years of history, was traditionally a stand alone application based on the 1-tier architecture, but developed during the 1990s and 2000s into full client-server solutions. Today, most CMMS are 3-tier solutions, but the n-tier solutions have the last couple of years grown in number under the term eCMMS, i.e. web-based CMMS solutions. Smaller firms still rely on 1- and 2-tier solutions. In many, especially larger, companies Enterprise Resource Planning (ERP) systems are utilised for the maintenance management. The ERP offers a seamless information flow for the main business processes (horizontal support) as well as decision-making power (vertical support), and are based on 3- or n-tier architectures.

A third type of MMIT is the special solution, mainly in the form of expert systems or decision support systems. The special solutions focus on providing additional support not found in the CMMS or ERP systems, for instance diagnostic power or decision support in form of key performance indicators. The special applications vary from 1-tier to n-tier solutions, and often there is a need for integrating them with the main maintenance management system. eMaintenance applications are solutions based on the service oriented architecture. Muller, Crespo Marques and Iung (2008) define eMaintenance as:

“Maintenance support which includes the resources, services and management necessary to enable proactive decision process execution. This support includes e-technologies (i.e. ICT, Web-based, tether-free, wireless, infotronics technologies) but also, e-maintenance activities (operations or processes) such as e-monitoring, e-diagnosis, e-prognosis, etc.”, Muller, Crespo Marques and Iung (2008 p.1167). eMaintenance is thus based on the SOA concept and often includes SaaS solutions.

In addition to the computerised maintenance management systems other sources for data retrieval are used. On process level production planning, control and supervision systems, devices and technology for condition monitoring and process control systems are used for technical data capture.

2.2.2 IT organisation and governance in maintenance

User friendliness, learnability and training possibilities are factors to consider when evaluating MMIT applications according to Braglia et al. (2006), but no studies are reporting explicitly on IT training. The IT maturity within the maintenance business context was addressed by Kans and Ingwald (2009), while research on IS organisation and IT governance is lacking. We could assume that the general definitions and theories of IT learning, organisation and governance are applicable also for maintenance.

2.2.3 IT impact in maintenance

The benefits of using MMIT have been expressed in a lot of publications, see for example Pintelon, Preez and Van Puyvelde (1999), Rao, Zubair and Rao (2002) and Mjema and

Mweta (2003). According to Jonsson (2000) IT investments in the maintenance area are of strategic importance. Moreover, Pintelon, Pinjala and Vereecke (2006) conclude that companies with a high level of maintenance strategy effectiveness are characterised by high and effective integrated computerised maintenance management system use. O'Donoghue and Prendergast (2004) reported on the impact of CMMS implementation in form of reduced cost of spares, uptime improvements, and increased equipment availability, reducing lead times, increased morale, reduction in unscheduled maintenance and streamlining of work orders schedules which resulted in reduced maintenance cost and increased production output. In addition, impacts in safety and security could be seen, such as more reliable production or less injuries. In Candell, Karim and Soderholm (2009) the positive impacts of eMaintenance on the dependability, safety and life-support costs of critical systems, such as airplanes, were highlighted.

3. STUDY PRESENTATION

In 2008-2009 a survey regarding MMIT utilisation in Swedish firms was conducted. The survey consisted of a web-based questionnaire and additional interviews for describing three perspectives of IT utilisation: functionality gaps, IT procurement, and overall IT practises. This paper reports on the last perspective.

3.1 Questionnaire study design

The web-based questionnaire was designed in the tool Query and Report by Artisan, <http://www.artologik.com/en/SurveyAndReport/Home/SurveyAndReport.aspx>, and was

tested internally within the department as well as with five industrial partners. After minor changes in the design, the questionnaire consisted of 29 questions in total, divided into four groups: Company descriptive (Questions 1-6), Maintenance related descriptive (Questions 7-19), IT use related questions (Questions 20-24) and IT procurement related questions (Questions 25-29). Extracts from the questionnaire are found in Appendix A. For this study, questions from all four groups were utilised. Company and maintenance descriptive were used as background information regarding the companies and to determine the organisational maturity. The IT maturity aspect was also captured in form of the IT systems intensity for different industries. Questions from the third group were used for depicting the technical aspects (IT systems type and IT architecture), while IT procurement related questions were utilised for the social aspects (Perceived impact) and the socio-technical aspects, in this study restricted to IT organisation and governance (IT procurement decision, systems ownership and participation in IT procurement). Questions from all groups were also utilised as test variables in the non-parametric analysis, see section 3.3.

The population consisted of plants where the maintenance is performed in-house. The study was delimited to plants belonging to following industries (based on the Swedish Standard Industrial Classification (SE-SIC) 2002): Petrochemical, Pulp and Paper, Wood and Timber, Steel and Metalwork, Automotive, Pharmaceutical, Chemical, Food, and Energy. The database from Swedish Centre for Maintenance Management, which was used for selecting respondents, contained 381 respondents meeting the set up criteria. Before distributing the questionnaires the respondents were personally contacted by telephone. 177 participants could not be reached by telephone and were removed from the study, and

an additional eight respondents stated that they could not participate by various reasons. This resulted in 196 respondents to which questionnaires were sent during September 2008 to February 2009 by e-mail. Of the 196 questionnaires sent 71 was answered and returned, representing a response rate of 36%.

3.2 Respondents descriptive

The respondents represented all industries of the population, see Figure 3. Steel and metal work and food industry dominated, while automotive industry was represented by only one respondent. Over half of the study participants were from the process industry, see Figure 4. The batch processing industry was also well represented with 21 respondents.

Figure 3. Industry type

Figure 4. Production type

The main part of the plants have been in operation for more than ten years, see Table 1. Only five plants were recently established, whereas the youngest establishments were from 2003. The oldest plant still in operation was from 1858 and the median value was 1966. The plants were mainly medium to large sized. The smallest plant employed ten persons and the largest 2500. Median number of employees was 250.

Table 1. Plant characteristics

Age of the current operation		Number of employees	
Less than 10 years	5	Lower than 50	2
Between 10 and 50 years	32	Lower than 250	31
More than 50 years	25	250 or more	35
Total	62	Total	68

Maintenance was most commonly organised as an own department, see Table 2. In 17 cases, the maintenance was organised as a part of the production. Three other organisational patterns were represented: maintenance as fully outsourced, maintenance and production in partnership, and maintenance as a part of production supported by a central maintenance

department. The time distribution denotes the average time for maintenance related activities in percentages. Main part of the time was spent on executing maintenance, while follow up was given around one tenth of the time. One fifth of the time was spent on planning. Table 2 also accounts for an attitude question regarding the impact of maintenance. Most respondents perceived maintenance as something that does contribute to company strategic goals. Notable is that no respondent selected the alternative “not true”.

Table 2. Maintenance characteristics

Maintenance organisation		Time distribution		Maintenance contributes to company strategic goals	
Own department	50	Planning	20	Completely true	35
Part of production	17	Execution	70	True to some extent	26
Other	4	Follow up	9	Not true to some extent	9
				Not true	0
Total	71	Total	99	Total	70

3.3 Analysis design

Three types of tests have been utilised for statistical analysis: Kruskal Wallis nonparametric test, crosstabs and nonparametric Mann Whitney tests. The Kruskal Wallis test was performed for studying differences between groups for a number of test variables. The dependent variables list is Systems ownership, Investment decision, Perceived fit to needs and Perceived benefit and the variables tested for were Plant age, Number of employees, Industry type, Production type, Maintenance organisation, IT systems type, Systems architecture, Systems ownership and Investment decision. As can be noted, the dependent and the independent variable list have some variables in common, as one dependent variable could be an independent factor for another depended variable. Crosstabs were utilised for describing distribution between groups for all variables with significant

differences in the means according to the Kruskal Wallis test, but not for determining statistical significance between the groups due to the large amount of cells with expected count less than five. Instead, the Mann Whitney test was utilised. We chose to report the Kruskal Wallis and Mann Whitney test results in form of crosstabs for each variable that showed significance at the 0.05 level, thus excluding the results with no significance.

4. MAINTENANCE IT PRACTICES

This section accounts for findings from the survey following the socio-technical model described in section 2. The technology used covers the technical system, technology procurement and governance covers the socio-technical system, and technology impact covers the social system.

4.1 Technology used

For the architecture, four generic types of architectures were identified: stand-alone, mainframe, client-server and web based architectures. The first two represent 1 or 2-tier solutions while the latter are 3 or n-tier solutions. Most respondents ran client-server solutions, see Figure 5. Web based solutions were found at 14 plants. Stand alone and mainframe architectures were rarely used: only 7 out of 68 had such.

Figure 5. IT architecture

The types of IT systems in the study were classified into following categories: CMMS, ERP, Production systems (production planning, control and supervision systems), Specially designed systems (in-house developed or non-standardised systems) and other systems, for example expert systems and systems for decision support, project planning or inventory management. A multi-choice question was utilised for capturing the types of IT systems used. The respondents could therefore select none up to five different types of systems. Three respondents did not use any IT system at present. The rest, 68 respondents, used one up to five different types of IT systems for maintenance management, see Figure 6. Most commonly used is the CMMS. 32 respondents use ERP systems, and almost a third used a production system. Amongst other solutions software for inventory control, calibration, planning, document handling, product development, cost control, failure alert and control, and for reliability-centred maintenance decision-making were mentioned.

Figure 6. IT systems used

Table 3 accounts for the combinations of IT systems used. The main part of the respondents used only one IT system, and the CMMS was dominating in this group. When two or three systems were utilised a combination of ERP, CMMS and a special solution was most common. Ten cases utilised all of the specified types. It is notable that the use of ERP systems in almost all cases was combined with the use of a CMMS.

Table 3. Combinations of IT systems used

One system		Two systems		Three systems		Four or five systems	
CMMS	19	ERP, CMMS	7	ERP, CMMS	6	ERP, Production	6
ERP	3	Production, CMMS	5	ERP, Production	4	ERP, Production	2
Other	3	CMMS, Specially designed	3	Production, CMMS	3	All alternatives	2
Production	1	ERP, Other	1	CMMS, Specially designed	1		
				ERP, CMMS	1		
Total	26	Total	16	Total	15	Total	10

The IT intensity within the different industries is reported for in Table 4. Due to small group sizes we only account for results between the five largest industries. In the rightmost

column an index for IT intensity is found based on number of respondents and total amount of IT systems within the group. The total amount of systems is delimited to range between zero and five, as it is based on the results of the multi-choice question regarding IT systems used, see Figure 4. If we compare the different industries with the total respondents, we find that wood and timber industry, steel and metal work and food industry were utilising fewer IT systems compared to the average, while pulp and paper and chemical industry utilised more systems than the average.

Table 4. IT systems intensity

Group	# of respondents	IT systems total within the group	IT intensity index
Chemical industry	9	24	2,7
Pulp and Paper	10	30	3,0
Wood and timber	9	11	1,2
Steel and metalwork	17	29	1,7
Food industry	13	21	1,6
Others	12	28	2,3
Total responses	70	146	2,1

4.2 Procurement and governance

The socio-technical aspects covers IT governance and procurement characteristics in form of three factors: where the IT investment decision is made, the systems ownership, and the participants in the purchasing process.

4.2.1 IT investment decision

The purchase decision was captured by a single-choice question. Three predefined working areas were given: maintenance, production and IT. A fourth choice was open for other working areas. Of the 69 respondents that answered this question four stated that they have

no IT system. In Figure 7 the results for the 65 remaining answers are found. 65% of the respondents stated that maintenance is making the decision, while IT or production makes the decision in about 1/3 of the cases. The group others includes four cases where the decision was made centrally, either by the central administration or by the (group) management team.

Figure 7. The Working area that makes the purchase decision

The statistical test results for the variable IT investment decision are accounted for in Table 5, indicating that IT investment decision could be explained by following factors: the maintenance organisation, the use of CMMS and which working areas participate in the procurement. Significant differences were noted for participation of maintenance and IT. In addition, the systems ownership showed significant differences, but we chose to account for these findings in the next crosstab (Table 6). Large differences could be found in expected and real group count for variables describing organisation type if IT decisions are made by

production. This indicates that if the investment decision was made by production, the maintenance activities were organised as a part of production to higher extent than as an own department. The Mann Whitney test did not give any significant readings for this though, so the differences cannot be statistically verified.

Table 5. Test results for IT investment decision

IT investment decision		Maintenance organisation ^a			Use of CMMS ^a		in purchasing ^a		purchasing ^a		Total
		Own dept.	Part of prod.	Other	No ^b	Yes ^b	No ^c	Yes ^c	No	Yes	
Maintenance	Count	31	9	2	1	41	1	41	7	35	42
	Expected Count	29,7	9,7	2,6	4,5	37,5	5,8	36,2	6,5	35,5	42
	% within column	67,4%	60,0%	50,0%	14,3%	70,7%	11,1%	73,2%	70,0%	63,6%	64,6%
	% of Total	47,7%	13,8%	3,1%	1,5%	63,1%	1,5%	63,1%	10,8%	53,8%	64,6%
Production	Count	2	6	1	2	7	1	8	1	8	9
	Expected Count	6,4	2,1	0,6	1	8	1,2	7,8	1,4	7,6	9
	% within column	4,3%	40,0%	25,0%	28,6%	12,1%	11,1%	14,3%	10,0%	14,5%	13,8%
	% of Total	3,1%	9,2%	1,5%	3,1%	10,8%	1,5%	12,3%	1,5%	12,3%	13,8%
IT	Count	10	0	1	4	7	6	5	0	11	11
	Expected Count	7,8	2,5	0,7	1,2	9,8	1,5	9,5	1,7	9,3	11
	% within column	21,7%	0,0%	25,0%	57,1%	12,1%	66,7%	8,9%	0,0%	20,0%	16,9%
	% of Total	15,4%	0,0%	1,5%	6,2%	10,8%	9,2%	7,7%	0,0%	16,9%	16,9%
Other	Count	3	0	0	0	3	1	2	2	1	3
	Expected Count	2,1	0,7	0,2	0,3	2,7	0,4	2,6	0,5	2,5	3
	% within column	6,5%	0,0%	0,0%	0,0%	5,2%	11,1%	3,6%	20,0%	1,8%	4,6%
	% of Total	4,6%	0,0%	0,0%	0,0%	4,6%	1,5%	3,1%	3,1%	1,5%	4,6%
Total	Count	46	15	4	7	58	9	56	10	55	65
	Expected Count	46	15	4	7	58	9	56	10	55	65
	% within column	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
	% of Total	70,8%	23,1%	6,2%	10,8%	89,2%	13,8%	86,2%	15,4%	84,6%	100,0%

a Significant differences stated at the 0.05 level between groups according to Kruskal Wallis H test

b Significant differences stated at the 0.05 level between groups No and Yes according to Mann-Whitney U test

c Significant differences stated at the 0.05 level between groups No and Yes according to Mann-Whitney U test

The Mann Whitney analysis did show significant differences between groups not utilising a CMMS and those using a CMMS. If maintenance was making the purchasing decision, it is more likely that a CMMS was used. Similarly, if IT was making the decision, the CMMS was used to less extent than expected. The Mann Whitney test also revealed differences between groups where maintenance representatives were part of the purchasing compared to where maintenance was not participating in the purchasing process. If maintenance was making the decision, maintenance was also involved in the purchasing to higher extent than

expected, while if IT was making the decision, maintenance was involved to less extent than expected.

4.2.2 Systems ownership

In 2/3 of the cases, the system used maintenance management was owned by maintenance, see Figure 8. In 17 cases IT was the systems owner. Three respondents stated that the system was owned by production, and four stated other owners than the predefined. Of these cases, one respondent had no IT system and one used only a simple spreadsheet application.

Table 6 reports on the nonparametric test results for the factor systems ownership. Only one factor, IT investment decision, showed significant differences between variables as well as between groups for systems ownership as dependent variable, but as mentioned above, there were differences noted for IT investment decision as dependent variable too. These two variables seem to depend on each other to large extent. The results show differences in expected count and actual count for several groups. If maintenance owned the IT system, maintenance was more likely to have made the decision, while production and IT showed up lower counts than expected. Where IT owned the system, maintenance was to less extent taking the decision, while IT does it to higher extent than expected.

Figure 8. IT systems owner

4.2.3 Participants in the purchasing

For describing the participants in purchasing, a multi-choice question with five predefined alternatives was used. A sixth category others was also given. The results are found in Figure 9. Most common was to involve representatives from maintenance and IT. Representatives from production, finance and purchasing were also involved in many cases. Only one respondent mentioned other working areas than the predefined: the group management.

Table 6. Test results for systems ownership

Systems ownership		IT investment decision ^a				
		Maintenance ^{b, c}	Production ^b	IT ^c	Other	Total
Maintenance ^{d, e}	Count	37	2	3	2	44
	Expected Count	28,4	6,1	7,4	2	44
	% within column	88,1%	22,2%	27,3%	66,7%	67,7%
	% of Total	56,9%	3,1%	4,6%	3,1%	67,7%
Production	Count	1	2	0	0	3
	Expected Count	1,9	0,4	0,5	0,1	3
	% within column	2,4%	22,2%	0,0%	0,0%	4,6%
	% of Total	1,5%	3,1%	0,0%	0,0%	4,6%
IT ^d	Count	4	3	7	1	15
	Expected Count	9,7	2,1	2,5	0,7	15
	% within column	9,5%	33,3%	63,6%	33,3%	23,1%
	% of Total	6,2%	4,6%	10,8%	1,5%	23,1%
Other ^e	Count	0	2	1	0	3
	Expected Count	1,9	0,4	0,5	0,1	3
	% within column	0,0%	22,2%	9,1%	0,0%	4,6%
	% of Total	0,0%	3,1%	1,5%	0,0%	4,6%
Total	Count	42	9	11	3	65
	Expected Count	42	9	11	3	65
	% within column	100,0%	100,0%	100,0%	100,0%	100,0%
	% of Total	64,6%	13,8%	16,9%	4,6%	100,0%

a Significant differences stated at the 0.05 level between groups according to Kruskal Wallis H test

b Significant differences stated at the 0.05 level between groups Maintenance and Production according to Mann-Whitney U

c Significant differences stated at the 0.05 level between groups Maintenance and IT according to Mann-Whitney U test

d Significant differences stated at the 0.05 level between groups Maintenance and IT according to Mann-Whitney U test

e Significant differences stated at the 0.05 level between groups Maintenance and Others according to Mann-Whitney U test

Figure 9. Working areas participating in the purchase of IT

4.3 IT investments impact

As mentioned in section 2.4, the actual impact of IT investments is hard to measure. Therefore, the perceived impact of the investment is addressed this study rather than the real impact. Table 7 accounts for two attitude questions regarding the impact of IT investments. We find that the main part of the respondents perceived the IT investments as beneficial and aligned to real needs within maintenance.

Table 7. IT investment impacts

Pruchased IT systems are	connected to real needs	beneficial for the maintenance
Completely true	31	29
True to some extent	18	21
Not true to some extent	11	11
Not true	4	4
Total	64	65

Tables 8 and 9 account for the results of the nonparametric test made for the investment impact factors. The perceived alignment of IT support to maintenance needs seem to vary by CMMS use, use of other systems and IT investment decision. CMMS users were more satisfied with their IT support than non CMMS users. They perceived the IT support as fit to needs and beneficial to higher degree than expected. Differences in perceived fit to maintenance needs could also be noted between groups where maintenance is making the decision compared to where production or IT is making it. The investments decided upon by maintenance or production resulted in higher satisfaction than expected, while investments where IT made the decision resulted in lower satisfaction than expected.

Table 8. Test results for perceived fit to needs

Apprehended fit to needs		Use of CMMS ^a		Use of other systems ^a		IT investment decision ^a					
		No ^b	Yes ^b	No	Yes	Maintenance ^c		Production ^d	IT ^{c, d}	Other	Total
Low	Count	2	2	1	3	1	0	3	0	4	
	Expected Count	0,4	3,6	3,5	0,5	2,7	0,4	0,7	0,2	4	
	% within column	28,6%	3,5%	1,8%	37,5%	2,4%	0,0%	27,3%	0,0%	6,3%	
	% of Total	3,1%	3,1%	1,6%	4,7%	1,6%	0,0%	4,8%	0,0%	6,3%	
Fairly low	Count	2	9	11	0	6	1	3	1	11	
	Expected Count	1,2	9,8	9,6	1,4	7,3	1,2	1,9	0,5	11	
	% within column	28,6%	15,8%	19,6%	0,0%	14,3%	14,3%	27,3%	33,3%	17,5%	
	% of Total	3,1%	14,1%	17,2%	0,0%	9,5%	1,6%	4,8%	1,6%	17,5%	
Fairly high	Count	2	16	17	1	11	2	4	1	18	
	Expected Count	2	16	15,8	2,3	12	2	3,1	0,9	18	
	% within column	28,6%	28,1%	30,4%	12,5%	26,2%	28,6%	36,4%	33,3%	28,6%	
	% of Total	3,1%	25,0%	26,6%	1,6%	17,5%	3,2%	6,3%	1,6%	28,6%	
High	Count	1	30	27	4	24	4	1	1	30	
	Expected Count	3,4	27,6	27,1	3,9	20	3,3	5,2	1,4	30	
	% within column	14,3%	52,6%	48,2%	50,0%	57,1%	57,1%	9,1%	33,3%	47,6%	
	% of Total	1,6%	46,9%	42,2%	6,3%	38,1%	6,3%	1,6%	1,6%	47,6%	
Total	Count	7	57	56	8	42	7	11	3	63	
	Expected Count	7	57	56	8	42	7	11	3	63	
	% within column	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	
	% of Total	10,9%	89,1%	87,5%	12,5%	66,7%	11,1%	17,5%	4,8%	100,0%	

a Significant differences stated at the 0.05 level between groups according to Kruskal Wallis H test

b Significant differences stated at the 0.05 level between groups No and Yes according to Mann-Whitney U test

c Significant differences stated at the 0.05 level between groups Maintenance and IT according to Mann-Whitney U test

d Significant differences stated at the 0.05 level between groups Production and IT according to Mann-Whitney U test

Table 9. Test results for perceived benefit

Apprehended benefit		Use of CMMS ^a		Use of other systems ^a		
		No ^b	Yes ^b	No	Yes	Total
Low	Count	2	2	1	3	4
	Expected Count	0,4	3,6	3,5	0,5	4
	% within column	28,6%	3,4%	1,8%	37,5%	6,2%
	% of Total	3,1%	3,1%	1,5%	4,6%	6,2%
Fairly low	Count	3	8	11	0	11
	Expected Count	1,2	9,8	9,6	1,4	11
	% within column	42,9%	13,8%	19,3%	0,0%	16,9%
	% of Total	4,6%	12,3%	16,9%	0,0%	16,9%
Fairly high	Count	1	20	20	1	21
	Expected Count	2,3	18,7	18,4	2,6	21
	% within column	14,3%	34,5%	35,1%	12,5%	32,3%
	% of Total	1,5%	30,8%	30,8%	1,5%	32,3%
High	Count	1	28	25	4	29
	Expected Count	3,1	25,9	25,4	3,6	29
	% within column	14,3%	48,3%	43,9%	50,0%	44,6%
	% of Total	1,5%	43,1%	38,5%	6,2%	
Total	Count	7	58	57	8	65
	Expected Count	7	58	57	8	65
	% within column	100,0%	100,0%	100,0%	100,0%	100,0%
	% of Total	10,8%	89,2%	87,7%	12,3%	100,0%

a Significant differences stated at the 0.05 level between groups according to Kruskal Wallis H test

b Significant differences stated at the 0.05 level between groups No and Yes according to Mann-Whitney U test

5. RESULTS AND RESULTS DISCUSSION

The main part of the participants of this study represents organisations that traditionally would be characterised as mature regarding IT use. They are established plants mainly from process industry in the range from medium to large sized businesses. We can also see that the main part represents a traditional maintenance organisation, where the focus is put on the execution of maintenance activities. Moreover, they perceive their business unit as contributing positively to the overall corporate goals.

When we look at the IT practices, we find:

- High use of business specific IT solutions, in this case CMMS
- Lower use of company wide IT solutions, e.g. ERP systems, and when it is used, it is often in combination with a CMMS
- Low IT intensity, in average two systems are used for maintenance management purposes
- The client-server model to be dominating, followed by n-tier solutions
- IT governance is to high extent tied to the maintenance function both in form of investment decision, systems ownership and IT procurement participation
- That IT investments are perceived as beneficial and connected to real needs

The IT intensity was rather low: in average two systems were used for maintenance management. The IT intensity differed over the industry types, having highest intensity in pulp and paper and lowest in wood and timber. This might be explained with IT maturity,

i.e. that pulp and paper are better in utilising IT than wood and timber, but an alternative explanation could of course be that the IT systems supporting wood and timber are more specialised for their processes, thus requiring few extra IT systems, and vice versa for pulp and paper. The first explanation seems to be more probable according to previous research, but a closer examination of differences in IT practices depending on industry type would be of interest. The reason for the variance in type and number of systems used could depend on several factors, such as maintenance strategy applied, size and type of production, level of integration between maintenance and production or the maintenance organisation. This study does not reveal which factors that actually affect the situation, and therefore more research could be done within this area.

The high focus on maintenance function specific IT solutions and IT governance imply that the focus of IT is for vertical support rather than horizontal or network support. If you own the IT systems and the IT procurement project, you tend to focus on a solution that is directed on improving your working area, rather than a corporate overall ultimate solution. If we compare the statistical results regarding IT governance, two interesting patterns appear. The use of CMMS varies with the IT decision; CMMS are used if maintenance makes the decision, and is used to less extent if IT makes the decision. Maintenance is also involved in the purchase and is system owner if they make the decision, while they are involved to less extent if IT is making the decision and stands as system owner. This indicates that there exist at least two types of IT governance strategies; the most common decentralised, where maintenance manages the IT investments and the less common

centralised where IT investments are handled by a central body. More research directed at IT governance strategies and their impacts on maintenance would be of interest.

The study participants were satisfied with their IT investments and perceived the IT system as aligned to real needs. This illustrates the connections between the technical, the socio-technical and the social systems: A certain type of IT system and a certain type of IT governance strategy would result in positive business impact.

6. CONCLUSIONS

In conclusion, the question whether industry is ready to adopt new IT concepts within maintenance could be answered saying yes – and no. From the perspective of the current situation, let us outline some opportunities for the future but also some challenges that have to be overcome.

Maintenance is a business unit with high level of decentralisation and function orientation with regard to IT practices. Moreover, the work area specific IT solutions currently used seem to match the needs of maintenance to higher extent compared to corporate wide information systems such as ERP systems. The further implementation of eMaintenance solutions would, from this perspective, likely to be successful. One challenge is low technology maturity, where the current systems are run on 1- to 3-tier solutions. From an integration perspective, the legacy systems could be hard to fit with more advanced information technology. In addition, the decentralised governance implies that maintenance

has to take responsibility for the purchase, operations and maintenance of the systems themselves. With more advanced technology, the need of support will increase, which would put more stress on the maintenance staff, or require external help from the IS organisation or the supplier. The decentralisation might also bring economic challenges, where investments in advanced technology simply do not fit into the current budget. It will be a major challenge for the maintenance organisation to justify such an investment. The SaaS concept could become a way to overcome some of these challenges: SaaS suits an organisation with low IT maturity as it distributes the operations, maintenance and support to a third part.

The results accounted for in this paper brings novel perspectives on MMIT practices by combining the technology used with organisational issues such as impact and governance. A major contribution is the highlighted possibilities and challenges for implementing advanced information technology in maintenance. This had not been achieved without the holistic perspective of the IT practices. The socio-technical approach suggested in this paper shows the tight interrelationship between different factors, layers and systems. The approach also gives many implications for further research. In previous studies, as well as this one, the aspects of training and education are neglected. These aspects have impact on the usability and utility of an IT system, and more research on strategies applied for training and education, as well as for describing the impact of training would be needed. The study also pointed out additional areas for further research: IT maturity and IT governance, and their impacts on the IT systems utility.

As a practical implication, the study results could be used to highlight state-of-the-art of MMIT, and thereby set the topic on the corporate agenda for setting the future direction of IT investments in maintenance. The results could for also be used for benchmarking purposes, comparing maintenance IT practices against other corporations.

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