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This is the accepted version of a paper published in *International Journal of Services Technology and Management*. This paper has been peer-reviewed but does not include the final publisher proof-corrections or journal pagination.

Citation for the original published paper (version of record):

Kans, M. (2018)

IT governance from the operational perspective: a study of IT governance strategies applied within maintenance management

International Journal of Services Technology and Management, 24(1-3): 263-288

<https://doi.org/10.1504/IJSTM.2018.090336>

Access to the published version may require subscription.

N.B. When citing this work, cite the original published paper.

Permanent link to this version:

<http://urn.kb.se/resolve?urn=urn:nbn:se:lnu:diva-71129>

IT governance from the operational perspective – a study of IT governance strategies applied within maintenance management

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Abstract: This paper investigates the existence and effects of different IT governance strategies on the operative level of manufacturing industries. The study is based on a mixed research method including statistical analysis of questionnaire data and a qualitative analysis of interview material. The operational business unit that is being studied is maintenance and its management. Several types of IT governance strategies existed within this business unit according to the study, and the decentralised was the most common. The different strategies had both a positive and negative impact on the business unit, but the federal IT governance strategy seems to overcome some of the problems in the others. The results indicate that there might be other characteristics worth testing than the ones used in this study, for instance the size of the business unit.

Keywords: IT governance strategies; Centralised strategy; decentralised strategy; Federal strategy; Mixed study research; Cluster analysis; Non-parametric test; Story-telling

Reference to this paper should be made as follows: Kans, M. (xxxx) 'IT governance from the operational perspective – a study of IT governance strategies applied within maintenance management', *Int. J. Services Technology and Management*, Vol. X, No. Y, pp.000–000.

Biographical notes: Mirka Kans is an Associate Professor of Terotechnology at Linnaeus University in Southern Sweden. She achieved a Masters in Computer Science in 2001 and her PhD in 2008. Her research focus lies within data and information systems for industrial management, and especially on data and IT requirements for maintenance management and how to support maintenance by means of IT to achieve cost-effectiveness. Industrial business management and automation strategies are other research topics. The research has resulted in more than 50 journal and conference articles. She is also active in developing the education practices and curriculum according to student centered and active learning concepts and in close collaboration with industry. She is an expert in terotechnology.

This paper is a revised and expanded version of a paper entitled 'IT governance strategies utilized within maintenance' presented at the 24th International Congress on Condition Monitoring and Diagnostics Engineering Management: Advances in Industrial Asset Integrity Management, Stavanger, Norway, 30 May to 1 June 2011.

1 Introduction

Information technology (IT) is an integrated part of any business today, and the corporate goals are hardly met without the support of IT. Consequently, planning the procurement and taking care of the IT assets after purchase is a matter of high importance. The management and coordination of all efforts throughout the IT system's life cycle is covered by the term IT governance. It is commonly understood that IT governance concerns the management and control of corporate IT resources. Sambamurthy and Zmud (1999) highlight IT infrastructure management, IT use management and project management as major areas of IT governance. Weill (2004, p.3) define IT governance as 'specifying the framework for decision rights and accountabilities to encourage desirable behaviour in the use of IT'. The desirable behaviour is such behaviour which is consistent with the corporate vision, strategy and values. Different strategies for IT governance exist, for example the centralised governance where IT resources are handled in a standardised form throughout the corporation by a central organisation, or the decentralised, where IT is handled autonomously on the business unit level (Sambamurthy and Zmud, 1999). The governance strategy applied will affect the effectiveness of the business. Weill (2004) for instance shows that the return on assets (ROA) is higher when the IT governance is strong. It is also important to design the IT governance processes to align with corporate governance processes because both shape the capabilities required to achieve strategic goals (Heart et al., 2010).

The purpose of this study is to investigate the effects of different IT governance strategies on the operative level of manufacturing industries, in this article specifically with focus on maintenance operations and the maintenance management. The operational level of an enterprise is where the IT governance strategy is effectuated and the effects of the applied IT governance strategy become apparent. Therefore it is quite suitable to study the consequences of a specific IT governance strategy at the operational level. Activities on the operative level are structured into business units. A business unit, according to Business Dictionary.com (<http://www.businessdictionary.com>), represents a specific business function which has a dedicated manager and its definite place on the organisational chart. Business units are also called departments, divisions or functional areas.

The chosen function, i.e., maintenance, provides the manufacturing with technical support in form of repairs, monitoring and preventive measures in order to keep the technical assets in a state in which they can perform as intended (British Standard, 1993). Effective maintenance requires support for the management in form of computerised maintenance management applications, such as computerised maintenance management systems (CMMS), enterprise asset management (EAM) systems or specific maintenance management modules in enterprise resource planning (ERP) systems. The alignment of the IT support to business needs is assumed as quite visible for the maintenance

management: having the inappropriate IT support will affect the management, which in turn affects the effectiveness of maintenance conducted. Similarly, the effects of various IT governance strategies will be quite visible, provided that one can determine the IT governance strategy in use. To achieve the formulated purpose, the study aims at answering the following specific questions:

- 1 Which IT governance strategies are applied for the maintenance management IT applications?
- 2 What is characterising these strategies?
- 3 What are the effects of IT governance strategies for the maintenance management?

The study is conducted by using a mixed methods research approach. The first two questions are handled through a use of statistical analysis of questionnaire data, while interview material is used to depict question three. Thus, both quantitative and qualitative methods are utilised. Some researchers claim that quantitative and qualitative methods cannot be combined and the focus is often set on the differences rather than the similarities amongst research methods (Johnson and Onwuegbuzie, 2004). The mixed method strategy has nevertheless been successfully applied for over 60 years, for instance as a form of between-methods triangulation (Johnson et al., 2007). A general definition of mixed research method is proposed by Johnson et al. (2007, p.123) as:

“...the type of research in which a researcher or a team of researchers combines elements of quantitative and qualitative research approached (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration.”

For this study, either a quantitative or a qualitative approach could have been chosen, but it would have restricted the understanding of the phenomena at the same time. The mixed research was chosen to gain the strengths involved in combining both approaches. For this study, the following strengths in particular could be gained, as described by Johnson and Onwuegbuzie (2004):

- words, pictures, and narratives can be used to add meaning to numbers
- can answer broader and more complete range of questions
- can add insights and understanding that might be missed when only a single method is used
- qualitative and quantitative research used together produce more complete knowledge
- a researcher can use the strengths of an additional method to overcome the weaknesses in another method.

For describing general patterns, such as the existence of IT governance strategies, the statistical data processing method is well suited. Storytelling, i.e., listening to people working on the operative level could provide an in-depth understanding of the area of study. In this study, the number of survey respondents, 71 in total, is relatively small. One reason is that the total population (maintenance managers in producing companies in Sweden) is comparatively small. The small sample size restricts the choice of statistical

analysis methods, as well as the result interpretation. Additional interview material was therefore gathered in parallel with the survey data, so both methods could support each other.

The disposition of the article is as follows: In the next section the concept of IT governance is discussed with respect to two main factors; which decisions are to be made and by whom. Section 3 introduces the reader to the study and in Sections 4 to 6 the questionnaire and interview data are analysed with respect to the research questions formulated above. The article ends with drawing some general conclusions regarding IT governance strategies and their effects on the operative level, including implications for further research.

2 IT governance

IT governance is quite a well-researched area, but still in need of further studies. Much of the previous research has been quantitative, see for instance Weill and Woodham (2002), Weill (2004), Verhoef (2007), Heart et al. (2010), Bart and Turel (2010), Dong (2011), and Nfuka and Rusu (2011). Quantitative studies help us explore governance patterns, see for instance the work by Weill and Woodham (2002) and Weill (2004), or reveal factors which could explain success and failure in adopting governance strategies such as in Verhoef (2007), Simonsson et al. (2010) and Nfuka and Rusu (2011), but they cannot describe the complexity of the concept or depict effects of strategies applied. For this purpose qualitative studies are more appropriate, such as the ones conducted by Sambamurthy and Zmund (1999) and Gwillim et al. (2005). Sambamurthy and Zmund (1999) studied the complexity of IT governance in form of multiple contingencies and their influence on the IT governance strategy while Gwillim et al. (2005) revealed the lack of formal IT governance drivers and post evaluation of IT projects in two case studies. Moreover, the focus of research has been on CEO and CIO level and to explain overall enterprise effects rather than describing the effects of governance strategies on the operational level. Few papers have been published with focus on a particular business area such as the one by Dong (2011), who studied the connection between IT governance decision execution and customer relationship management (CRM) systems diffusion.

2.1 IT governance structures and archetypes

A traditional way to depict the distribution of decision making rights for IT is the matter of centralisation versus decentralisation. Decision power allocated to lines or divisions of business is described as a decentralised IT governance strategy, while decision power which is gathered into one single location (assumably on overall business level) is a centralised strategy (Peterson, 2004). Flexibility, IT customised for business needs, good overview of overhead costs and close partnership between IT and the business units are some of the advantages with a decentralised strategy. The main disadvantages are higher infrastructure costs, loss of control, difficulties in applying global standards and centralised negotiations, and duplication of data and staff (Pearlson and Saunders, 2010). The advantages and disadvantages of the centralised strategy are basically the opposite to the decentralised. An attempt to reduce the disadvantages with both strategies is called federalism. The federal strategy distributes decision making power between a central IS function and the business units. With the federal strategy, which is an enterprise wide

vision, strategy and IT architecture could be applied while securing the business units' input and control over IT investments. In addition, economies of scale could be maintained, and the important IS skills could be guaranteed.

Weill (2004) extended the three strategies into six IT governance architectures: business monarchy, IT monarchy, feudal, federal, IT duopoly and anarchy. Business monarchy and IT monarchy are examples of centralised strategies, and where decisions are made either by corporate executives or IT executives. The feudal architecture is a typical decentralised strategy, where the decision is made by business unit leaders. The anarchy archetype could also be seen as a decentralised strategy, where the decision is made by each individual user. The federal archetype describes a federal strategy. The IT duopoly is not directly connected to any strategy. Instead, it could either be central (corporate executives and IT executives makes decisions) or decentralised (business unit leaders and IT executives makes the decision).

2.2 The decisions connected to IT governance

Weill (2004) states that IT governance is about how decisions are made and who makes the decision rather than which decision to make. Nevertheless, we find several authors directly or indirectly addressing the decisions that need to be made. Sambamurthy and Zmud (1999) give examples of decisions connected to IT infrastructure management, IT use management and project management. IT infrastructure management decisions concerns hardware and software platforms, network and data architectures, and standards for procurement and utilisation of IT. IT use management regards the prioritising, planning and daily operations of IT. Project management decisions mix technical knowledge with project management capabilities. Gwillim et al. (2005) highlight the post project evaluation decisions. Simonsson et al. (2010) mention IT portfolio decisions for aligning IT investments with business strategy. One of the most cited list of IT governance decisions is created by Weill (see Weill and Woodham, 2002; Weill, 2004), where the following five key decisions are proposed:

- 1 IT principles – high-level statements about how IT is used in the business.
- 2 IT architecture – defines the technical integrated setup of IT in the business. The architecture also consists of policies and rules for the use of IT.
- 3 IT infrastructure strategies – strategies defining shared and centrally coordinated IT capabilities within the business. This could for instance be support and network capabilities.
- 4 Business application needs – the specification of IT applications needed for the business.
- 5 IT investment and prioritisation – IT investment decisions and project prioritising decisions.

Combining the types of decisions to be made with strategies or archetypes of IT governance gives an overview of how IT is governed in enterprises. This was made by Weill, and he also studied the governance patterns of the top performing enterprises. The study comprised 256 enterprises representing 23 different countries and was addressed to the CIOs (Weill, 2004). Table 1 summarised the findings from this study. It could be seen that the business monarchy and IT monarchy archetypes, i.e., centralised strategies, are

commonly found amongst the top performers for all types of decisions except business application needs. The federal approach as well as the duopoly was also highly used, especially for business unit needs and IT investment decisions. None of the top performers used decentralised strategies to a high extent.

Table 1 Top three IT performers

	<i>IT principles</i>	<i>IT architecture</i>	<i>IT infrastructure</i>	<i>Business application needs</i>	<i>IT investment and prioritising</i>
Business monarchy	3	3	3		2, 3
IT monarchy		1, 2	1, 2		
Federal				1, 3	
Feudal					
Anarchy					
Duopoly	1, 2			2	1

Note: Numbers 1–3 represent the top three performers.

2.3 *IT governance from the operational perspective*

As described in 2.2, the business unit manager could be a decision making partner for some of the strategies (the decentralised and the federal) while the centralised excludes the business unit manager in the decision making process. The IT governance decision making authority is seldom allocated solely to the operational level though. Of the six archetypes described by Weill (2004), two address a decision making authority on the operational level: the feudal and the anarchy. Neither of these was common in the study, and of the top performing enterprises none were found using these archetypes. When the feudal archetype was utilised, the decision rights were mainly for specifying business needs of IT (business application needs).

Even if not being directly involved in the formulation of the corporate IT governance strategy, the business unit manager will still be involved in the decision making especially on IT project level. Therefore, when trying to reflect IT governance strategies from the operational point of view, it is not fruitful to address all of the five decision areas mentioned in Section 2.2. This is because the business unit manager will not possess the information required for answering questions regarding strategic dimensions of IT governance, such as ‘What is the corporate IT strategy?’ or ‘What infrastructure approach is applied in the enterprise?’. Instead, let us focus on three generic questions of IT governance as raised by Weill (2004): who makes each type of decision, who can give input to a decision, and how these people are held accountable for their role. Moreover, we need to find specific decision making situations, in which the business unit manager might have insight and that reflects the IT governance strategy. Such a natural situation is the IT procurement project. For IT projects, three questions are applicable: ‘Who is making the decision’ would refer to the corporate level, individual business unit or individual manager who is making the decision, ‘Who can give input to a decision’ is reflected in the business units participating in the project, and ‘Who is held accountable for the decision’ could be found by defining the systems owner.

These questions will be used as theoretical framework when analysing the IT governance strategies applied for maintenance IT support, but before going into details with the data analysis, let us introduce the study in which the data was collected, as well as the study participants.

3 Study design and study participants maintenance

This section covers the concept of maintenance, defining the term and describing the maintenance work processes, the management of maintenance as well as the utilisation of IT for supporting the work flow and the management.

3.1 Maintenance management

Maintenance is a postproduction function aiming at preserving and extending the life of a system. The formal definition, according to British Standard (1993), describes maintenance as providing the manufacturing with technical support in form of repairs, monitoring and preventive measures in order to keep the technical assets in a state in which they can perform as intended. The maintenance action to be taken is determined by the policy and strategy applied. A maintenance policy describes the interrelationship between whom that carries out maintenance, where to carry out maintenance and the set of maintenance actions to be carried out (British Standard, 1993). The maintenance strategy, defined in the standard EN 13306:2010 as a management method used in order to achieve the maintenance objectives and goals, describes the focus of the maintenance organisation in order to reach maintenance goals, which could be realised using different policies for different objects to be maintained. EN 13306:2010 describes three general maintenance strategies: corrective, predetermined and condition-based (SIS, 2010). Corrective maintenance aims at fixing assets after the failure occurs, while the other strategies aim at preventing failures by periodic inspections and maintenance actions (predetermined) or by monitoring the asset condition offline or online and carrying actions based on this (condition-based). The latter is often referred to as predictive maintenance. The maintenance strategy could also be connected to the overall business strategy. Pintelon et al. (2006) describe different stages of maintenance strategy effectiveness, where maintenance is being a service function that somewhat reluctantly has to be carried out and therefore getting low or no attention by corporate investors in lower stages, to being a potential contributor to competitive advantages and therefore taken into consideration for major capital investment decisions in higher stages.

Maintenance management is defined in EN 13306:2010 as all activities of the management that determine the maintenance objectives, strategies, and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision, improvement of methods in the organisation including economical aspects (SIS, 2010). The maintenance workflow process comprises according to EN 13460:2002 eight main activities: Study-define, work planning, work schedule, work order release and assignment, carry out the work, closure of work, production of reports, and report analysis (SIS, 2002). The workflow is generic for all maintenance strategies, but the information need and activities differ. Corrective maintenance requires failure diagnostics, spare parts planning, work order scheduling and management, and follow-up of the maintenance activities. Predetermined maintenance on the other hand requires

analysis of historical data, work order planning, scheduling and management, as well as follow-up. Data acquisition and manipulation, state detection and health assessment as well as for prognostics assessment and advisory generation are main activities in condition-based maintenance (ISO, 2007). Based on these data, the maintenance actions could be planned and work orders released. A comprehensive list of information and IT functionality requirements for supporting the workflow is found in Kans and Ingwald (2012).

3.2 IT supporting the maintenance workflow

IT applications for maintenance management are supporting the planning, execution and follow up of maintenance activities, i.e., the full workflow. These systems could be divided into three main groups: CMMS, ERP systems and special solutions, mainly in the form of expert systems or decision support systems (Kans, 2013). CMMS's are independent maintenance specific IT systems which in most cases could be fully or partly integrated with other business administration systems. The CMMS's provide basic functions for corrective maintenance and for planning and carrying out preventive maintenance, such as scheduling, plant inventory, stock control, cost and budgeting and maintenance history. Some of the CMMS's also supports condition monitoring. ERP systems cover the full information need of the company, from finances and inventory management to production management. ERP systems are often module based giving the possibility for the enterprise to fit the system to the business needs. The maintenance management module has similar functionalities as a CMMS, and one of the major benefits is the seamless integration with other ERP modules. The special solutions focus on providing additional support not found in the CMMS or ERP systems, for instance by providing diagnostic and prognostic power or decision support in form of key performance indicators. In addition, production planning, control and supervision systems as well as systems for condition monitoring and failure diagnostics are commonly used for maintenance management, mainly for data retrieval.

An emerging concept that combines the managerial and technical perspective of maintenance management is e-maintenance. Muller et al. (2008) describe e-maintenance as "maintenance support which includes the resources, services and management necessary to enable proactive decision process execution", thus addressing the managerial perspective, but also cover the technical aspect by stating: "This support includes various e-technologies (e.g., ICT, web-based, and wireless) as well as e-maintenance activities (e.g., e-monitoring, e-diagnosis, and e-prognosis), in order to support production and business". According to a comprehensive review of e-maintenance research by Aboelmaged (2015), the managerial perspective covers the strategic dimension of e-maintenance as a decision support as well as the process, policy and procedure dimension changing the way maintenance is managed and adding new types of maintenance activities. Moreover, e-maintenance could be seen as a subset of e-manufacturing and e-business (Han and Yang, 2006). E-maintenance lets the company to synchronise maintenance actions with the operation leading to cost-effectiveness and reduced disturbances in the production. This requires integration of information as well as processes (Macci and Garetti, 2006).

The technical aspect of e-maintenance covers the development of e-maintenance applications, but also the way e-maintenance could be applied in various businesses and industries. Examples of developed and tested e-maintenance systems are found in

Rasovska et al (2005), Han and Yang (2006), Lung et al. (2009) and Pistofidis et al. (2012). Different technical solutions for data acquisition, diagnostics/prognostics, and for decision making are the core of e-maintenance. Sensors, radio frequency identification tags, wireless technologies and standards for ensuring integration, such as MIMOSA, are examples of solutions supporting data acquisition while web services, decision support systems and mobile devices support the diagnostics, prognostics and decision making (Lung et al., 2009). Intelligent prognostic capability is a cornerstone for e-maintenance according to Lee et al. (2006). Such tools have been developed for various application areas; see for instance Lung et al. (2009) and Asplund et al. (2014). Lee et al. (2006) point out the need for generic and scalable tools for prognostics, for instance in form of the Watchdog Agent described in the article, which could be integrated into the existing IT infrastructure. The advanced e-maintenance applications are also referred to as Maintenance 4.0 (Kans et al., 2015). Maintenance 4.0 is characterised by computerisation with the help of cyber-physical systems and 'internet of things' in the form of intelligent, self-learning systems that identify potential failures, make diagnostics and prognostics, and trigger maintenance actions.

4 Study design and study participants

4.1 Study design

The study was conducted in two steps during 2008–2009. First, a questionnaire survey was conducted, and thereafter additional interviews were carried out. The questionnaire was designed in 2008 using a web-based software tool and was tested utilising colleague expertise and industrial representatives. After minor changes in the design, the questionnaire was sent to the participants during September 2008 to February 2009. The questionnaire was directed towards managers within maintenance or asset management. 381 plants, all found in the database from the Swedish Centre for Maintenance Management, met with this criterion and were selected for a possible participation in the survey. Telephone contact was made with representatives in the plants asking whether they would like to participate in the survey before sending out the questionnaire. Of the 381 possible respondents in the database 177 could not be reached by telephone and were removed from the study, and an additional eight respondents stated that they could not participate because of various reasons. 196 surveys were sent out, and of these 71 surveys were returned representing a response rate of 36%. The participants belonged to the following industries [based on the Swedish Standard Industrial Classification (SE-SIC) 2002]: pharmaceutical, petrochemical and chemical (9), pulp and paper (10), wood and timber (9), steel and metalwork (17), automotive (1), food (13), and energy (6). Numbers in parenthesis are denoting the amount of respondents.

In connection with this survey, five interviews were made during the autumn of 2009. The main reason for conducting these interviews was to collect qualitative data that could complement the quantitative analysis made on the questionnaire results. The interviews were carried out over telephone and were recorded. Each interview lasted for about half an hour. The interview questions were based on the interview template found in Appendix A, but the respondents were given freedom to go into particulars or keep a more overview description if they wanted. The interviews were transcribed after completion and the data were processed in a simple matrix table. In this article three of

the five interviews are utilised. These three respondents were picked out after the statistical analysis (described in the next section) had been carried out. The three interviews correspond fairly well to the results gained from the statistical analysis by representing cases from different clusters. By listening to their stories, we could gain better understanding of the impact and characteristics of different IT governance strategies. By combining quantitative and qualitative data, we can thus create a more holistic view of the problem area.

4.2 Participants

The respondents are mainly representing industries with process (37 out of 70) or batch (21 out of 70) manufacturing. Mass production is applied in eight of the plants and only four plants belong to shop floor manufacturing. The maintenance is organised as an own department in 50 of the plants and as a part of production in 17 plants. In four cases there are other organisational forms: partnership, outsourced and a combination of centralised and decentralised organisation, where the maintenance is part of production.

The main part, or 68 respondents, use IT systems for maintenance management. Nearly 90% use a traditional CMMS, and about half use an ERP system, see Table 2. Almost a third uses a production system. Specially designed solutions are found in a third of the companies. Other systems used for maintenance purposes are solutions for inventory control, calibration, planning, document handling, product development, cost control, failure alert and control, and for reliability-centred maintenance decision-making. Mark: a multi-choice question was utilised for defining the types of IT systems used. The respondents could therefore select none up to five different types of systems they use, and the total responses exceed the number of respondents. Most respondents run their IT system using the client-server architecture. Stand alone and mainframe architectures are rarely used: only 7 out of 68 had such (five main frames and two stand-alone). Web-based solutions were found at 14 plants. The decision to purchase IT for maintenance management is to a high extent an internal matter within the maintenance organisation. 65% of the respondents stated that maintenance was making the decision. If maintenance is not the decision making authority, the decision is made by production or by the IT department. Only in rare cases are the decisions made centrally, either by the central administration or by the (group) management team.

Table 2 IT-related characteristics

<i>IT systems used</i>		<i>IT system architecture</i>		<i>Decision maker</i>		<i>Systems ownership</i>	
CMMS	59	Web based	14	Maintenance	42	Maintenance	47
ERP	32	Client-server	47	Production	9	Production	3
Production system	21	Mainframe	5	IT	11	IT	17
Specially designed	23	Stand alone	2	Other	3	Other	4
Other	10						
Total	145	Total	68	Total	65	Total	71

A multi-choice question with six different alternatives was utilised to capture the working areas involved in the purchasing of IT. The predefined alternatives were maintenance, production, IT, finance and purchase. A sixth category named others was also given. If chosen, the respondents were asked to specify the working area involved. The results are

found in Figure 1. Most common is to involve representatives from maintenance and IT. In one case the alternative ‘others’ was used, where the respondent stated that group management was involved.

Figure 1 Working areas participating in the purchase of it (see online version for colours)

4.3 Data analysis

The statistical analysis of the questionnaire data was made in SPSS v. 15.0. The data analysis was made in two steps: first a cluster analysis was conducted to investigate whether different IT governance strategies were utilised for computerised maintenance management support. Thereafter, the clusters were analysed to find differences between groups utilising non-parametric tests. The non-parametric test is used due to the relatively small sample size.

5 IT governance strategies applied in maintenance

5.1 Cluster analysis

Three factors describing the IT governance were used as input for the cluster analysis: systems ownership, IT investment decision, and working area participation in the purchase process, represented as eight variables of ordinal scale. These factors are in accordance with the theoretical discussion of Section 2.4. Table 3 lists the variables and possible values of each variable.

Table 3 Variable description

Variable name	Values
Systems ownership	Maintenance, production, IT, other
IT investment decision	Maintenance, production, IT, other, IT system not used
Maintenance involved in purchasing	Yes, no
Production involved in purchasing	Yes, no
IT involved in purchasing	Yes, no
Finance involved in purchasing	Yes, no
Purchase involved in purchasing	Yes, no
Others involved in purchasing	Yes, no

A hierarchical cluster analysis was first performed to define suitable number of clusters. A two or three cluster alternative was deemed the most suitable, as changes in the agglomeration coefficient were high for these, and therefore K-means analyses were performed on a two cluster and a three cluster alternative respectively. The two and three cluster alternatives did not differ for two of the clusters (clusters 1 and 3 in Table 4), while a new pattern emerged in the three cluster alternative (cluster 2 in Table 4). The new pattern was seen as important to consider, since it is adding to the understanding of IT governance strategies. Therefore, the final solution is based on a three cluster alternative. In the following, a description of each cluster characteristics is given.

Table 4 Final cluster centres

	<i>Cluster</i>		
	<i>1</i>	<i>2</i>	<i>3</i>
<i>Number of cases in each cluster</i>	<i>40</i>	<i>19</i>	<i>6</i>
Systems ownership	Maintenance	IT	Maintenance
IT investment decision	Maintenance	Production	Other
Maintenance involved in purchasing	Yes	Yes	No
Production involved in purchasing	Yes	Yes	No
IT involved in purchasing	Yes	Yes	Yes
Finance involved in purchasing	No	No	Yes
Purchase involved in purchasing	Yes	Yes	No
Others involved in purchasing	No	No	No

The first cluster, to which over 60% of the cases belong to, is dominated by the maintenance organisation. Maintenance owns the system, participates in the purchasing and triggers the decision. The purchasing is a cross-functional process, where representatives from production, IT and the purchase function participates together with maintenance representatives. The second cluster, to which about 30% of the cases belong to, is characterised by cross-functional purchasing, and the procurement decision was triggered by production. The ownership of the purchased system is not assigned to the production though, neither to maintenance. Instead, the IT function is assigned as the owner. The third cluster is the smallest cluster group with 6 out of 65 cases, and involves maintenance to a low extent. Maintenance is assigned as the systems owner, but is not actively participating in the purchase process. The purchase decision is made by upper management and the purchase is carried out by IT and finance.

In Table 5, the distances between cluster centres are accounted for. No cluster distinguishes itself from the others in regards to the distances. This means that the clusters are evenly distributed with respect to distances. The statistics found in Table 6 shows up some interesting results though. From the cluster mean square values one can see that the three variables adding most to the clusters are *systems ownership*, *IT investment decision* and *maintenance involved in purchasing*. When running cluster analysis using only these three variables the same results were reached as for the original eight-variable-solution. The cluster alternatives were the same and the cases were grouped into the same clusters. This implies that the number of variables used could be reduced without losing any cluster characteristics.

Table 5 Distances between cluster centres

<i>Cluster</i>	<i>1</i>	<i>2</i>	<i>3</i>
1		2,352	2,630
2	2,352		2,290
3	2,630	2,290	

Table 6 Cluster statistics

	<i>Cluster</i>		<i>Error</i>		<i>F</i>	<i>Sig.</i>
	<i>Mean square</i>	<i>df</i>	<i>Mean square</i>	<i>df</i>		
Systems ownership	26.803	2	0.149	62	179.541	0.000
IT investment decision	20.413	2	0.235	62	86.938	0.000
Maintenance involved in purchasing	1.144	2	0.088	62	12.974	0.000
Production involved in purchasing	0.403	2	0.249	62	1.619	0.206
IT involved in purchasing	0.203	2	0.130	62	1.562	0.218
Finance involved in purchasing	0.132	2	0.247	62	0.532	0.590
Purchase involved in purchasing	0.610	2	0.235	62	2.596	0.083
Others involved in purchasing	0.005	2	0.016	62	0.306	0.738

5.2 Results from the cluster analysis

The cluster analysis suggested a three cluster solution. These clusters represent well the three different IT governance strategies described in Section 2. The first cluster conforms to a decentralised IT governance strategy, where maintenance drives the investment decision, participates in the procurement and owns the system. The second cluster, where the production makes the investment decision, the IT owns the system and maintenance is participating in the procurement could be seen as a kind of federal governance strategy. The third cluster is describing a centralised IT governance strategy where the decision is made by the upper management, where maintenance is not participating in the procurement, but where maintenance owns the system. The decentralised IT governance strategy was in this study most common, which is not in accordance with the previous studies such as Weill (2004).

There are several possible interpretations to the reasons behind this. One possible interpretation is that maintenance is not a part of the corporate IT strategy and thus not budgeted for, and therefore has to handle the IT investments within the maintenance budget. Another is that the decentralised government is deliberately applied for maintenance because maintenance people are the best suited to define maintenance requirements. As long as the situation within maintenance alone is known, without knowing the overall corporate strategies, these interpretations are merely indications of how to proceed with future research.

6 Characteristics of the IT governance strategies

6.1 Analysis of differences between clusters

The three clusters were tested for in-between group differences by the means of the non-parametric Kruskal-Wallis test. The independent variable list is found in Table 7. A list of specific values each variable could be given are found in the rightmost column.

Table 7 Independent variable list

<i>Question category</i>	<i>Variable</i>	<i>Values</i>
Plant descriptive	Industry type	Chemical, pulp and paper, wood and timber, steel and metal work, automotive industry, food industry, energy, other
	Production type	Process, mass, batch, shop floor
Maintenance descriptive	Maintenance organisation	Own department, part of production, other
IT technology	Use of ERP	Yes, No
	Use of production system	Yes, No
	Use of CMMS	Yes, No
	Use of specially designed system	Yes, No
IT impact	IT architecture	Web-based, client-server, mainframe, stand alone
	IT investments are connected to needs	Not true, not true to some extent, true to some extent, completely true
	IT investments are beneficial	Not true, not true to some extent, true to some extent, completely true
Procurement aids	Use of consultant	Low, fairly low, fairly high, high
	Purchaser experience	Low, fairly low, fairly high, high
	User involvement	Low, fairly low, fairly high, high
	Pre-study	Low, fairly low, fairly high, high
	Systematic purchasing methodology	Low, fairly low, fairly high, high
	Systematic evaluation methodology	Low, fairly low, fairly high, high
	Project form	Low, fairly low, fairly high, high
	Others	Low, fairly low, fairly high, high

The clusters were tested on total 18 variables describing the plant, the IT use in maintenance and the aids used in IT procurement. The test results are found in Appendix B. Three variables showed statistical significance at the 95%-level: *use of CMMS*, *IT investments are connected to needs* and *user involvement*. This means that the clusters vary with respect to the values of these variables. We cannot tell from the results between which clusters there are differences, nor the way in which the values differ between the clusters. The Mann-Whitney U test was therefore utilised for finding differences between clusters at the 95% significance level.

Table 8 Mann-Whitney results

	Cluster number	N	Mean rank	Sum of ranks	Mann-Whitney U	Wilcoxon W	Z	Asymp. sig. (2-tailed)	Exact sig. [2* (1-tailed sig.)]
Use of CMMS	1	40	31.76	1,270.50	309.5	499.5	-2.371	0.018	
	2	19	26.29	499.50					
	1	40	32.46	1,298.50	201.5	354.5	-2.634	0.008	
	2	17	20.85	354.50					
	1	40	34.73	1,389.00	191	381	-3.436	0.001	
	2	19	20.05	381.00					
	Cluster number	N	Mean rank	Sum of ranks	Mann-Whitney U	Wilcoxon W	Z	Asymp. sig. (2-tailed)	Exact sig. [2* (1-tailed sig.)] ^a
Use of CMMS	1	40	24.43	977.00	83	104	-2.821	0.005	0.241
	3	6	17.33	104.00					
	1	40	25.18	1,007.00	53	74	-2.438	0.015	0.027
	3	6	12.33	74.00					
	1	40	23.95	958.00	102	123	-0.674	0.501	0.577
	3	6	20.50	123.00					
	Cluster number	N	Mean rank	Sum of ranks	Mann-Whitney U	Wilcoxon W	Z	Asymp. sig. (2-tailed)	Exact sig. [2* (1-tailed sig.)]
Use of CMMS	2	19	13.37	254.00	50	71	-0.602	0.547	0.687
	3	6	11.83	71.00					
	2	17	12.74	216.50	38.5	59.5	-0.917	0.359	0.392
	3	6	9.92	59.50					
	2	19	11.95	227.00	37	227	-1.382	0.167	0.221
	3	6	16.33	98.00					

Note: ^aNot corrected for ties.

The results from the Mann-Whitney test analysis are found in Table 8. The results are grouped by cluster pairs' comparison. First the results from comparing clusters 1 and 2 can be seen. The mean rank values suggest that cluster 1 is more likely to use a CMMS, to perceive IT as connected to business needs and to involve future users in the purchase process compared to cluster 2. The mean rank values furthermore suggest that it is more common to perceive IT investments as connected to business needs in cluster 1 compared to cluster 3. Lastly, the results from comparing clusters 2 and 3 are accounted for. No significant differences were found.

6.2 Results from the non-parametric test

The non-parametric tests suggest that the cases using a decentralised IT governance strategy perceive that the IT investment is more closely correlated to maintenance needs compared to the other strategies. The decentralised strategy is also utilising a CMMS and involves future users in the procurement more than the federal strategy type, while there were no statistical significance for these variables between the decentralised and the centralised government strategies. It seems like the more maintenance is involved in procurement, the better is the fit of IT to business requirements. The tests also show that the CMMS, which is tailored specifically for the maintenance purposes, is the preferred choice if maintenance has the control over the IT support. It is also interesting to reflect on the variables which did not show significance; none of the plant or maintenance descriptive variables showed significant differences between groups. One could therefore expect that different strategies are applied in various industries, production types and maintenance organisational setups. One could expect the maintenance organisation to have some influence in the strategy selection (with more centralised or federal strategies found where maintenance was not its own department and more decentralisation when maintenance was organised as a department of its own) but at least this study rejects this.

7 The effects of different IT governance strategies

In this section interview material is used to describe three cases of IT utilisation in maintenance. Based on these stories, the characteristics and the effects, both positive and negative, of a certain IT governance strategy for the maintenance function will be highlighted.

7.1 Case 1

This interviewee holds a position as production support manager, a position he maintained during his eight years at the plant. His previous experience covers positions like service technician, tool maker and machine constructor. The plant belongs to the metal processing industry and the production is mainly continuous. The maintenance is organised as a department of its own under production and employs four people. They perform corrective and preventive maintenance with the approximate ratio 60/40, i.e., corrective actions dominate. For the management they use a traditional CMMS licensed for five concurrent users. As additional support they use an overall equipment effectiveness (OEE) analysis system. The interviewee misses the integration between the CMMS and the OEE analysis system. Without it, he explained, he has not enough

support for analysing conducted maintenance and thus not enough support for maintenance improvement work. The interviewee foresees the next improvement step to be the ability to link the amount of maintenance work with the equipment capacity. As he says: "When production increases, maintenance should increase too".

Improvement work is conducted at the plant but recorded into separate sheets, which are coordinated with the CMMS through the use of common work order codes. The CMMS is seen as an inevitable asset. "I do not know how we would cope without it", the interviewee reflects. "You get more and more tasks all the time, and you have to work smarter all the time". The CMMS also leads to the decentralisation of maintenance planning, for instance in the form of operator driven planning. Handling the CMMS he finds easy, at least now when he is used to it. Maintaining the systems takes time, but 'if it is shared by the guys' it is manageable, the interviewee implies.

According to the interviewee, they use most of the functionality available in the CMMS, and unused parts are hidden. The original purchase included only basic functionality and was rather cheap: "We gave about 20 000 SEK for the system". They thereafter implemented the system in several phases, adding functionality when the organisation was ready. The vendor listens to the users, the interviewee says, which is both good and bad. The positive is that problems can be fixed. They faced some problems with the withdrawal of spare parts, which were solved after discussions with the vendor. The negative is when the vendor tries to satisfy all users, which results in a too complex system, he reflects. The implementation of a CMMS generally takes long time and some activities must be handled manually even if you have a CMMS, the interviewee continues. Failure notice is not integrated in their current CMMS, thus they do it manually. Purchasing the system was a complicated work. The interviewee was new at the position and to the plant when he was given the task to purchase a suitable CMMS. "It would have been ten times easier to buy the CMMS today", he says. The purchase was conducted with no support from others at the plant, but he had help from an external consultant, who suggested the current CMMS based on the plant and maintenance characteristics. The interviewee concludes the interview with describing his vision: everyone in the company should use the CMMS. It could for instance be used for safety inspections or for retrieving statistics to be used during board meetings.

7.2 Case 2

This plant belonging to the pulp industry has a centralised maintenance department called maintenance development and a central workshop, while the daily maintenance is carried out by satellite workshops. In total, about 120 persons are working with maintenance. The interviewee is manager of the maintenance development department, a position he has held for half a year. The interviewee has eight years of experience in total at the plant, for instance as project engineer. The main part of the maintenance are planned actions, and the share of predictive maintenance is high, while acute maintenance represents maximum 5% of the total work orders. They utilise an ERP system for maintenance management, which is integrated with the economy system, construction system and the OEE analysis and control system. Additional systems utilised are SCADA, a maintenance analysis system and the condition monitoring systems. The IT systems are administrated by different system governance groups, and the interviewee belongs to several of these groups. The governance group develops working routines and processes for the IT systems and keeps in contact with the vendor in upgrading and

license matters. The group also forms the core of a purchase project, to which end users and people from the purchase and IT departments are added. They work in a structured way with pre-studies including process mapping and vendor assessment, and written requirements specifications. The current ERP system was bought in 2002 and the selection strategy was to purchase a system already running on another plant within the corporation. The interviewee thinks the system fits the maintenance needs fairly well and only misses functionality for risk assessment. There are demands from the government on risk assessments of all work orders, and to make the risk assessment process easier, previous risk assessments made on assets should be easy to access.

The standardisation of functionality, especially the process flows, is brought up as a negative aspect. He finds the software developed for other businesses and therefore much of the functionality included, for instance for maintenance planning and preparation, are not applicable for his business, pulp and paper. While discussing the strengths, the standardised flows are once again mentioned, now in positive terms. "The best is that they are almost 100% coherent, the flows", he says. Integration is seen as an enabler and strength, but integrated systems bring problems too. If one transaction becomes incorrect it is hard to correct it. They use a standardised version of the ERP system. "The more you customise the poorer functionality", the interviewee reflects. Implementing a new ERP system gives the opportunity to change old and outdated work processes. The interviewee emphasises the vast information coverage of the ERP system that eases the execution of maintenance and gives basis for follow up and improvement of maintenance. The system provides good basis for the performance indicators they use, for instance cost per object. It is hard to show the true benefits of the system, though. The interviewee reflects: "You could play with the thought *Ok, let us remove the entire system, what would that mean?*". Most likely, he continues, they would have to hire a whole lot of more people to keep the same level of control.

7.3 Case 3

The interviewee has 35 years of experience at the plant, whereof fifteen years at the current position as automation engineer and specialist. The plant is within the food industry and the production is characterised by mass production. Maintenance is organised as a department of its own with traditional mechanical and electrical workshops, and some additional specialists, in total 17 people. The production is stopped three times a year for preventive maintenance and improvement work. Between the overhauls scheduled preventive and acute maintenance is conducted. The interviewee is in the middle of implementing an ERP system with the server located at the headquarters to replace an old IT system from the '80s. The choice of ERP system was made centrally and it will be implemented on all plants within the corporation. The interviewee is actively running the project at the plant and as he says: "...this I have been doing this for four years now". They have launched the inventory management and are in the middle of converting the preventive maintenance functionality from the old system into the new. Next step is to set up the work order handling module. Some activities, such as failure reporting, are handled manually. The system could be expanded with several functions if required. A revision function would for instance suit their business because they have scheduled major stops for maintenance. Expansions are put on hold at the moment though due to economic reasons. He also mentions installed functionality that they will not use at the moment; the calibration function. Calibration is important and conducted at the plant,

but documented on separate sheets. The responsible for the calibration is highly skilled and never makes a mistake the interviewee says, but as he is over 60 years old, changing the ways of working by introducing the ERP system for the documentation is not workable. The high age of maintenance personnel complicates the introduction of the system, especially when it is perceived as hard to learn and the threshold for use is high. “Most of the users are 50+. We have three that celebrate their 60th birthday this year”, the interviewee tells.

The conversion from the old to the new system faced some technical problems, for instance due to different item codes used in the corporation. They had some customisation of the system made to suit the maintenance needs. Classification information was for instance added to the items. But it is complicated when problems arise. “The support is really poor. If you get stuck somewhere or...there are always bugs in all systems”. The interviewee is in general satisfied with the ERP system and sees the benefits it bring to the maintenance organisation in form of easier access to information, automatic handling of purchasing from order to payment, and as support for planning and execution of maintenance. “It is all about what you put into the system”. The ERP system is a nice tool for maintenance and leads to shorter reparation time, he says. “All information about a certain object are gathered in one place, including documentation and tips of how we did last time we made a repair”. They have not made any maintenance follow up yet. “But the customer asked for information about tube changes and that I could provide”, he points out.

7.4 Analysis of the cases

The first case depicts a decentralised IT governance strategy. The purchase was planned and carried out by the maintenance and the solution was chosen primarily to meet maintenance management needs. The decision regarding which system to implement was solely down to the production support managers, i.e., a decision made by maintenance. The characteristics connected to the decentralised strategy, i.e., use of a CMMS, maintenance involvement in the purchase process and the apprehension that IT investments are connected to maintenance needs are all found in this story. They purchased a traditional CMMS and the interviewee was pleased with its functionality and usability, in the sense that the system fulfilled their current needs and could be extended to handle future needs. A decentralised strategy could bring problems with the integration of systems, especially if the systems to be integrated are owned by different business units and no central organisation coordinates the IT portfolio. The interviewee describes such a lack of integration. The decentralised strategy puts high demand on the governing organisation – in this case the maintenance department – in the form of skills, capacity and knowledge. It has to possess not only business specific knowledge, but also knowledge to select different IT solutions, to run purchasing projects, and to maintain the IT system, or at least its database, to mention a few. The story describes how the interviewee makes use of external expertise and the maintenance crew to support him with IT-related knowledge and capacity. He also faced the problem of fitting the purchase into existing budget, and therefore he adapted a strategy of continuous development of the initial solution. Positive effects are also seen: the interviewee finds the CMMS as well fitted for their needs. The maintenance is highly involved in the purchase, which adds to the possibility of finding the best solution. Also, the vendor is keenly aware of the users’ requests and tries to meet these requirements.

The second case is a bit harder to fit into any strategy. In pulp and paper, the maintenance is traditionally working closely with production, often in a matrix form. In this case, the purchase decision was made by maintenance, but unlike the first story, the governance strategy is more formalised in the form of administrative groups governing the systems. It is not a decentralised strategy, neither a centralised, but something in between, and could therefore fit into the federal strategy. The interviewee did not express that there was a problems with fitting the investment into the existing budget, and he described the purchase as a structured process in project form, i.e., the positive effects of having a centralised support functions. The use of administrative governance groups further indicated that there exists a centralised support organisation for IT. The ERP system suits the maintenance purposes fairly well even if it suffers from the standardisation problems you often face with standardised software. A positive aspect of the ERP software is the possibility to integrate with other IT systems, (such as has been done in this example. The interviewee did not reflect on any problems connected to the integration of systems, so it can be assumed that it is working in a satisfactory manner.

The third case is a typical example of a centralised strategy. The decision was made centrally in the corporation and the ERP system was enforced on all levels of the business. Several obstacles were reported by the interviewee. Firstly, the implementation spanned over a long period of time and the support was poor. The effects were seen in the form of poor or non-existent support for either a part of or the whole management of maintenance. Not being able to plan, report and follow up activities with satisfying continuity affects maintenance in possible a negative way. The interviewee did not mention any such negative effects but considering that only the inventory management and parts of the preventive maintenance modules were implemented, it can be assumed that other maintenance management activities are conducted manually or by using legacy systems. The ERP system is a business wide solution with little focus on the maintenance specific requirements. It also suffers from being not especially user-friendly; it is hard to learn and hard to manage. This in combination with old maintenance staff, a situation quite common in Swedish industry, makes the barrier to start using the system high. Another obstacle is the difficulty in customising and adapting the ERP system to the maintenance needs, because changes require costly consultants. The positive aspects are that maintenance was given the opportunity to replace the legacy system without the need to carry the procurement cost, and that systems operation, maintenance and development is taken care of centrally, giving the possibility for the maintenance organisation to focus on core maintenance activities.

7.5 Results discussion: what are the effects of applied IT governance strategies on maintenance?

Each IT governance strategy being used has both positive and negative effects on the maintenance function. A decentralised strategy increases the chances of good a good fit to their needs and, because this strategy is connected with the use of a traditional CMMS, the IT solution is developed to meet maintenance requirements. In Sweden, most CMMS used in industry are developed within the country, intended for the Swedish market. This could be a reason for the closeness to the vendor as described in story number one. Story one gives another aspect, a negative one, about the problems with integrating different software, which could stem from decentralised IT governance and no central support for IT development projects. Other negative points were described in story one: it could be

hard to fit a larger investment into the existing budget, and some IT-related capabilities, such as the ability to evaluate and select from different solutions, could be lacking. This affects the total time that could be spent on core activities, because someone has to make space for IT management and support activities in his or her total working time.

A centralised governance strategy puts less demand on IT-related capabilities, and therefore the maintenance organisation could focus on core business activities. It demands a good centralised support function though. If the IT support is poor, the work might take longer or even come to a standstill. A centralised strategy could, as in the case of story three, result in a standardised IT portfolio, which does not fit the specific business needs. It could also be hard to influence the purchase and decision from maintenance's point of view, because there are many interest parties with conflicting needs. Story three pointed out another obstacle: the long implementation and learning curve of the ERP system's maintenance module. Even if this obstacle is not directly connected to the governance strategy, but to the type of IT system used, it is an indirect effect of the centralised IT governance strategy resulting in the implementation of standardised cross-functional IT solutions.

Federal IT governance strategy as described in story two seems to over bridge some of the problems with decentralised and centralised strategies. There exist well defined and central IT support tools and functions, and a specific budget could be established for larger investments. Different systems could be integrated for achieving the best match with business needs. It requires efficient communication channels between different levels and functions though, otherwise the IT coordination and integration might fail.

8 Conclusions and further research

In this study, a combination of quantitative and qualitative approaches was used in order to reach a more holistic understanding of IT governance, specifically from the operational perspective. This approach has brought some interesting results with respect to IT governance in maintenance, and the authors believe that it could be utilised in further studies of other working areas as well. Moreover, the study shows that it is possible to describe effects of an IT governance strategy on the operational level.

We conclude that there exists several types of IT governance strategies within maintenance, and that the decentralised is the most common, according to this study. Maintenance differs in this perspective from the situation in general, where the federal governance strategy dominates. It might also be assumed that the decentralised strategy brings both general benefits and drawbacks in form of a good fit of IT support to business needs and a poorer IT control and negotiation position. The first assumption, i.e., benefits with the decentralised strategy, was supported by the Kruskal-Wallis and Mann-Whitney tests, while case one described many of the drawbacks of the decentralised strategy with a lack of a designated IT budget and IT capability.

More research is needed in order to understand the effects of applying a certain IT governance strategy on the business operational level and also what affects the choice of strategy. This is important in order to find the optimal IT governance policy which renders maximum effectiveness and return on investment. From the maintenance point of view, a decentralised strategy seems to be the most suitable, but this is from the operative managers' own perspective. The ability to assess the strategy in a wider perspective, for instance by applying suitable key performance indicators, is needed. The author would

also like to emphasise that the strategies applied within the business unit might differ from the overall corporate IT governance strategies. Therefore, it is important to study this area on a both organisational and corporate level.

Additional studies of what characterises governance strategies would also be of interest. The analysis of the stories indicates that there might be other characteristics worth testing than the ones used in this study, for instance the size of the maintenance organisation. Two of the stories (the ones using a centralised and a decentralised strategy respectively) represented small sized maintenance departments, while the one utilising a mixed (federal) strategy was considerably larger.

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Appendix A

Interview template

Respondent-related questions

- 1.1 Position
- 1.2 Number of years at the plant
- 1.3 Number of years in current position
- 1.4 Earlier positions

Plant-related questions

- 2.1 Type of industry
- 2.2 Type of production
- 2.3 Others

Maintenance-related questions

- 3.1 Type of maintenance
- 3.2 Maintenance organisation

Maintenance IT-related questions

- 4.1 Type of system
- 4.2 Procurement year
- 4.3 Modifications
- 4.4 Architecture and users
- 4.5 Main field of use
- 4.6 What is best with your system?
- 4.7 What are the weak points in your system?
- 4.8 Problems – exemplify
- 4.9 What do you miss in the system?
- 4.10 Unnecessary functions – which and why
- 4.11 Are you satisfied with the system?

IT procurement-related questions

- 5.1 How is IT procurement for maintenance made?
(participants, decision-maker, centralised/decentralised)
- 5.2 How are the requirements specified?
- 5.3 How do you find appropriate vendors?
- 5.4 How is the system selected? Methods, criteria for selection
- 5.5 How are IT investments followed up?
- 5.6 Problems – exemplify.

Appendix B

Kruskall-Wallis test results

	Cluster number			Cluster number			Cluster number				
	N	Mean	Rank	Chi-square	Asymp. sig.		N	Mean	Rank	Chi-square	Asymp. sig.
Industry type	1	39	32.67	3.155	0.206	IT investments are beneficial	1	40	35.95	3.402	0.183
	2	6	43.83				2	6	23.83		
	3	19	28.58				3	19	29.68		
Total	64						Total	65			
Production type	1	39	31.68	0.258	0.879	Use of consultant	1	40	33.03	3.567	0.168
	2	6	33.00				2	6	45.00		
	3	19	34.03				3	19	29.16		
Total	64						Total	65			
Maintenance organisation	1	40	33.89	2.639	0.267	Purchaser experience	1	40	36.98	5.257	0.072
	2	6	23.50				2	6	28.25		
	3	19	34.13				3	19	26.13		
Total	65						Total	65			
Use of ERP	1	40	32.44	1.206	0.547	User involvement*	1	40	38.18	11.781	0.003
	2	6	27.83				2	6	33.33		
	3	19	35.82				3	19	22.00		
Total	65						Total	65			
Use of production system	1	40	33.88	0.796	0.672	Prestudy	1	40	36.98	5.578	0.061
	2	6	27.92				2	6	25.75		
	3	19	32.76				3	19	26.92		
Total	65						Total	65			

Note: *Significance noted at the 0.05 level

Kruskall-Wallis test results (continued)

	Cluster number	N	Mean	Rank	Chi-square	Asymp. sig.	Cluster number	N	Mean	Rank	Chi-square	Asymp. sig.
Use of CMMs*		1	40	35.69	7.991	0.018	Systematic purchasing methodology	1	40	35.45	2.596	0.273
		2	6	25.67				2	6	23.83		
		3	19	29.66				3	19	30.74		
	Total		65					Total	65			
Use of specially designed system		1	40	32.88	0.031	0.985	Systematic evaluation methodology	1	40	34.31	1.569	0.456
		2	6	32.33				2	6	24.67		
		3	19	33.47				3	19	32.87		
	Total		65					Total	65			
IT architecture		1	40	34.05	0.553	0.758	Project form	1	40	34.26	0.583	0.747
		2	6	32.50				2	6	32.75		
		3	19	30.95				3	19	30.42		
	Total		65					Total	65			
IT investments are connected to needs*		1	40	37.14	10.490	0.005	Others	1	40	32.69	1.877	0.391
		2	6	18.75				2	6	38.92		
		3	17	24.59				3	19	31.79		
	Total											

Note: *Significance noted at the 0.05 level