Courtesy of Data Reimagined
(swbsconsultants@gmail.com)

ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/220399123

A method for assessing the business value of information system scenarios with an estimated credibility of the result

Article *in* International Journal of Services Technology and Management · November 2010

DOI: 10.1504/IJSTM.2010.029673 · Source: DBLP

CITATIONS
5

READS
1,005

3 authors, including:

Mathias Ekstedt
KTH Royal Institute of Technology
144 PUBLICATIONS **1,680** CITATIONS

SEE PROFILE

Per Närman
KTH Royal Institute of Technology
25 PUBLICATIONS **475** CITATIONS

SEE PROFILE

All content following this page was uploaded by Per Närman on 30 May 2014.

The user has requested enhancement of the downloaded file.

A method for assessing the business value of information system scenarios with an estimated credibility of the result

Magnus Gammelgård, Mathias Ekstedt, Per Närman
Royal Institute of Technology/ KTH, Dept. of Industrial Information and Control Systems, Osquldas väg 12 7tr, SE 100-44 Stockholm, Sweden

Abstract

This paper presents a method for assessing the business value of information system scenarios. The purpose of the method is to provide information system decision makers with high quality information about potential future scenarios at a relative low cost of investigation. The method features three frameworks; one for functional assessments of information system scenarios, one for non-functional assessments of information system scenarios, and finally a general business value taxonomy. The former two serve as an input structure to the latter one. The business various concepts in the business value taxonomy were prioritized by business managers to reflect the organization's business needs. A problem with estimating the business value of an information system scenario is that it is a very complex undertaking; there are a vast number of aspects that need to be assessed in order to get a correct result. To be cost efficient all of these aspects cannot be addressed so the results of the method will inevitably contain a degree of uncertainty. The method thus also provides an estimate of the uncertainty of its results. The method has been tested in a comprehensive case study at a large European power company.

1. Background

The evolution of the information system architecture at enterprises today can be seen as a constant process of introducing new systems and phasing out old ones. More than ever before these information systems are commercial-of-the-shelf products rather than the result of a clean slate development. And instead of a clean slate, enterprises typically have a large number of legacy information systems that are not the result of a holistic master plan (Linthicum 2000) (Reich 2003). As a result of the lack of proper information system planning, various information systems often contain an abundance of redundant functions. To further exacerbate the situation, information systems are often heavily interconnected in a way usually poorly understood by those in charge of information systems management.

An important aspect of information systems management concerns evaluating and choosing "to-be" architecture scenarios constructed of "prefabricated bricks", and decide on which scenario to implement (Wallnau et. al., 2002). The complexity of modern information systems makes it difficult to determine the best scenario for the responsible decision maker, a situation aggravated because of the lack of holistic evaluation tools that translates information system qualities into business value.

This general description can be exemplified with the architecture of asset management systems at a large European power company. Business-wise, asset management is the process of maximizing the value of the enterprise's accumulated physical assets (Morton 1999). This paper presents a method that was developed in order to help the power company to determine what asset management information system architecture to implement across the entire company. Since there were several asset management system solutions already deployed much knowledge of pros and cons of these solutions existed in the company. However, since this knowledge was distributed, it was difficult to compare the different scenarios in a fair manner. The purpose of developing and using this method was thus to provide decision support by assessing the business value impact of the different scenarios in an objective and comparable way. The method was not only to give business value estimations, but also to include information regarding the quality of the assessments, i.e. the certainty or the credibility of the results.

Providing a credibility estimate is something that is currently lacking in information system assessment methods. Moreover, existing IT-investment evaluation methods tend to be very general and make sweeping statements concerning complicated causal relationships without support; e.g. financial figures are estimated directly from changes in the IT infrastructure without presenting what part of the information systems that affect these financial figures (Strassman 1985) (Trigeorgis 1997) (Ballantine and Stray 1999), thus risking to oversimplify this complex area. When it comes to more information system oriented assessment methods (Meyerson 2001) (Schniederjans and Hamaker 2003) (Remenyi et al 1997) they on the other hand lack support for identifying the business value impact of the information systems.

The paper is organized according to the following structure: Chapter 2 gives a brief description of the method. Chapter 3 then delves into the details of the method. Chapter 4 discusses the generalizability of the method – what is constant over different assessments and what needs to be modified before use. Chapter 5 describes the case for which the method was originally developed. Chapter 6 contains some suggestions to (ongoing) future work.

2. Method outline

On the highest level of abstraction the method can be presented as in Figure 1.

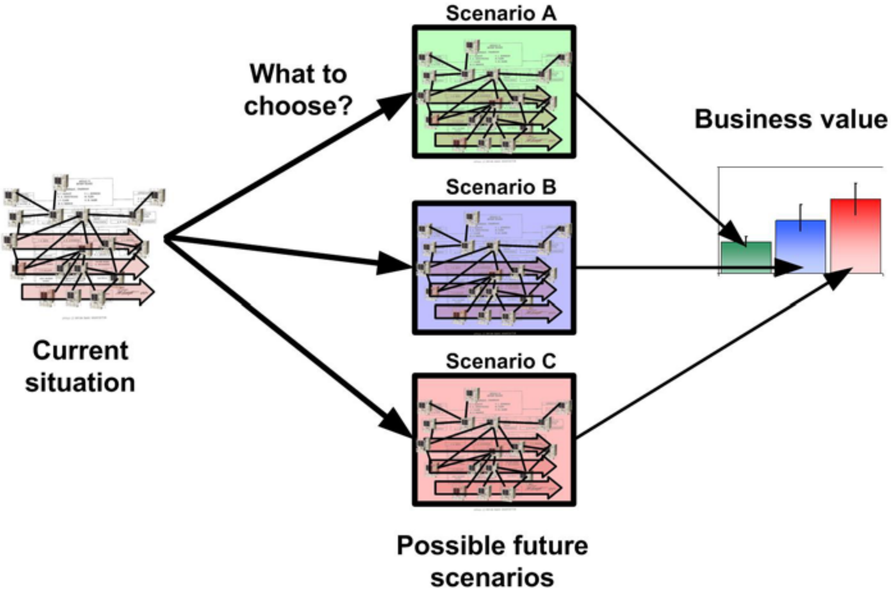

Figure 1: The method evaluates information system scenarios with respect to their business value contribution, i.e. the right hand side of the picture.

Given that there exist a few potential future information system architecture scenarios the method calculates an index of how much business value impact that each scenario generates. The method also provides an estimate of the certainty of the results to make the decision maker confident that the comparison is fair. Below, we firstly give an overview of what aspects that are evaluated in the scenarios, and secondly a general description is given on how these individual measurements are combined when calculating the numerical result.

2.1 The assessment frameworks

The method features three frameworks with a number of evaluation questions, see Figure 2.

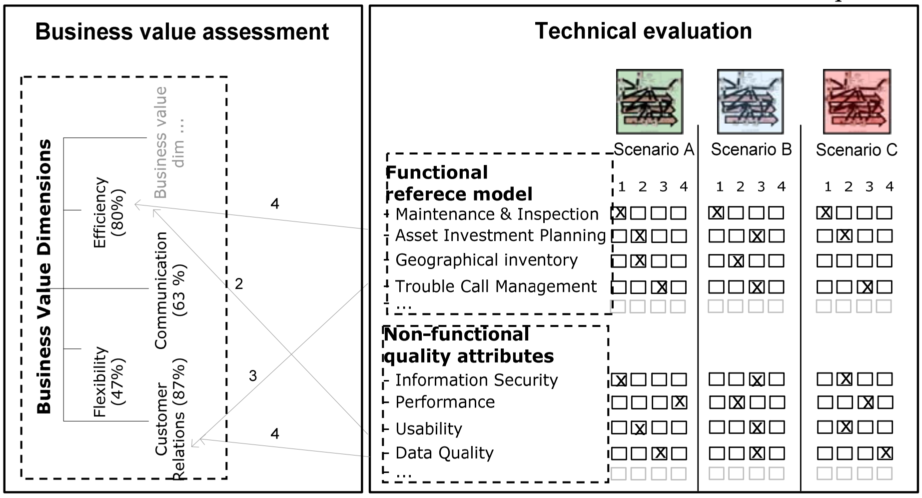

Figure 2: The main parts of the method. The three dotted boxes refers to the three framework described in the text below. The boxes with solid lines indicate the two main evaluations done in the method.

The first framework consists of a reference model of dimensions of business value. These dimensions are qualitative in nature and exclude financial metrics. The second assessment framework consists of a reference model of all potential functionality that can be implemented in information systems for asset management. The third framework consists of metrics for evaluating non-functional properties of information systems.

2.2 Combination of measurements

The three frameworks are connected to give a total estimate of business value. The technical side of the method yield evaluations of the functional and non-functional properties of information system scenarios. Data is collected by interviews with system experts and system users. These answers are aggregated into an individual estimate for each function of the functional reference model. At the business side, the business value impact of the functional and non-functional system properties is estimated by having system users identifying which technical properties that affect which business value dimensions. Finally, business executives prioritize the business dimensions according to their business importance. A total index for the business value is then calculated.

The method requires information from multiple sources. Low quality information will inevitably lead to low quality decision support and there is therefore a need for the decision maker to be able to judge the quality of the evaluation. Essentially there are two different sources of low quality information. Firstly the input; the answers may be incorrect. Consequently, the certainty of input data needs to be estimated. Secondly, in order to have a completely correct result, the amount of information needed is immense and economically impossible to gather. Thus, input data will be incomplete. The method needs to be able to state something about how this incompleteness affects the certainty of the final result. The method uses statistical mathematics taken from the Dempster-Shafer theory to make the uncertainty of results explicit (Yang and Xu 2002a) (Yang and Xu 2002b) (Dempster 1968) (Shafer 1976).

3. Detailed description of the method

This chapter provides the reader with an understanding of the inner workings of the method.

3.1 The functional property assessment framework

The most fundamental role of an information system is to provide functions, or services, to the business. Any method purporting to determine the business impact of information systems must somehow determine the degree to which the functions or services of the information system match the business's requirements. Many authors and methods have highlighted this, most prominently within the discipline of requirements engineering (Kotonya and Sommerville 1998) (Pressman and Ince 2000). Where requirements engineering generally is devoted to elicitation of functional requirements on information systems from the business, the method presented here assumes a predefined reference model of the business' functional domains. A functional reference model of the business makes it possible to map information system functions from different systems and allows for meaningful and fair functional evaluations.

The content of a functional reference model will vary with the business. This reference model may be derived by custom elicitation in the specific enterprise or it might be a reused reference model Chapter 4 briefly discusses the work that needs to be done in order to develop the reference model before applying the method.. The functional reference model used in the conducted case study is presented in Chapter 5.

3.2 The non-functional property assessment framework

Non-functional properties of information systems describe constraints on and qualities of the functional behavior of the system, e.g. security and performance. Unfortunately, no standard exist for exactly how to characterize or measure non-functional attributes. Methods such as the Architectural Trade-off Analysis Method (Kazman et. al. 2000) help with the structure for the analysis process but do not postulate any specific analyses. Non-functional properties are also often vague in nature. For instance, what does it mean that a system is secure, and how do we know that this is the case? To tackle this problem, the attributes are decomposed into more measurable and well-defined properties. An important step in the development of the method was thus to identify the exact measures to be used for the non-functional assessments.

The challenge of developing a framework for non-functional assessments of information system scenarios is that a complete and credible evaluation requires massive amounts of data. The limited resources available in today's business world make such exhaustive studies impossible. Consequently, the analysis framework must be reduced. The work with developing and reducing the assessment framework is illustrated in Figure 3.

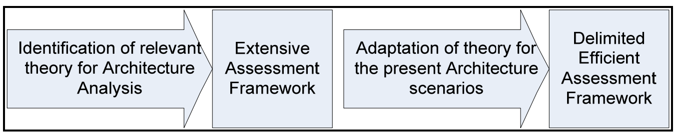

Figure 3: Schematic description of the assessment framework development.

Previous work on adapting non-functional properties for analysis of information systems is presented in (Lindström et. al. 2005) and (Gammelgård 2007b). In short, this work proposes a structure of the properties as described in Figure 4. The structure is similar to that used in ISO/IEC 9126 (ISO/IEC 2001), even though the specific categorization differs slightly from the standard.

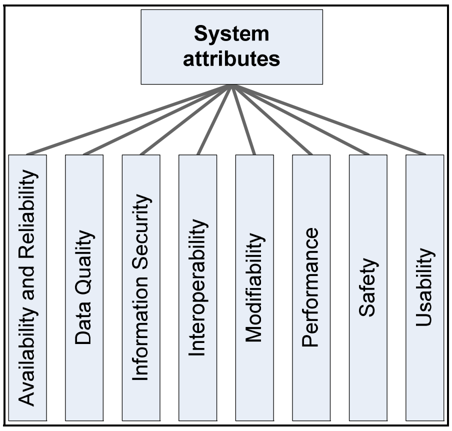

Figure 4: Non-functional properties of information systems.

To assess each one of the non-functional properties in Figure 4 is in itself quite an arduous task. To assess for instance the security of an information system scenario requires a thorough investigation of (possibly a great number of) firewalls, intrusion detection systems, encryption devices, etc. In order to determine how to assess these properties on an architectural scenario level, evaluation frameworks were developed based on literature reviews. The reviews covered between 5 and 50 sources per property. The resulting frameworks contained between 40 and 1100 metrics per property. To make the framework less cumbersome it was considerably reduced. A general description of the principles for this reduction is presented in Chapter 3 and in (Gammelgård et al. 2007b). The resulting assessment framework for the non-functional properties used in the presented case study is presented in Chapter 5.

3.3 The Business value assessment framework

This section presents the development method for the business value dimension framework and then proceeds to describe the content of the framework.

3.3.1 Description of method for developing the framework

The business value framework is based on an extensive literature study. The literature was searched for statements concerning the impact of information technology on business operations. Some 625 statements from 80 scientific sources were thus elicited. To make the framework less unwieldy to use these statements were then clustered according to their semantic and syntactic similarity. The references to this framework as well as the method behind the framework's development are described in (Gammelgård 2006a).

3.3.2 The business value assessment framework

The framework contains 25 categories of business values provided by IS/IT. The categorization is based on three views on the business. First, the business is looked upon as a black box and this group includes categories of business value related to the input and output of the business. The second group includes categories connected to the resources of the business needed to transform inputs into outputs. The third group of categories views the business as a group of interrelated components or activities and describes how IS/IT may benefit these components and activities.The three views are illustrated in Figure 5 have previously been presented in (Gammelgård et al. 2006a).

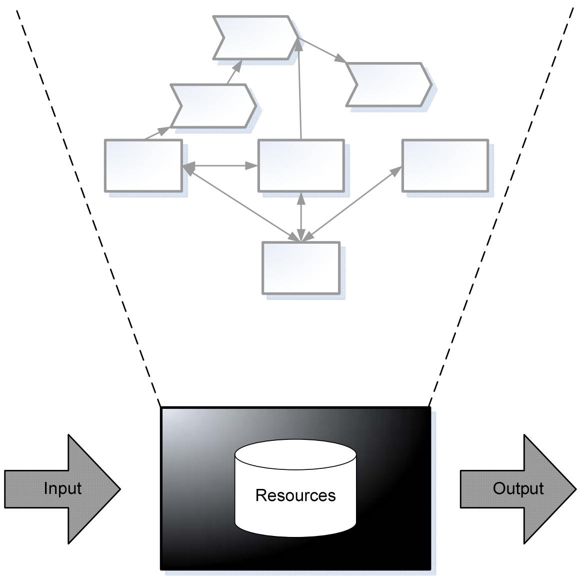

Figure 5: Illustration of the viewpoints used to group the benefits categories.

3.3.2.1 The business as a black box

When viewed as a black box the following categories are used: the *inputs* to the business are products and services from suppliers and the *output* are products or services to customers. There are also *external relations* to third parties related both to inputs and outputs of the organization but not exclusively to either side.

Input

- *Inbound logistics* refer to improvements related to the products/services that the company purchases from suppliers. This could for instance refer to the increased ability to control the quality of products and services from suppliers.
- *Supplier relations* refer to improvements related to the organization's relations with external suppliers through for instance new forms of co-operation.

Output

- *Customer relations* refer to improvements in the organization's relations with customers by giving for instance more accurate replies to customer questions.
- *Lock-in effects/switching costs*. Refer to the ability to prevent customers from choosing competing products, by for instance introducing loyalty programs.
- *Competitor relations* refer to improvements of the organization's relation to competitors through for instance increased bargaining power towards competitors.
- *New products/services* refer to an organization's degree of innovation which allows them to offer their customers new products or services.
- *Differentiations in products/services* refer to the ability to change or differentiate the products or services that are offered, for instance by making it easier to tailor products to customer needs.
- *Quality of products/services* refer to improved quality of the products or services offered, for instance by reducing product errors.
- *Deliveries* refer to improvements of the deliveries of products or services to customers, by for instance being able to offer more timely deliveries.

Third party relations

- *Third party relations* refer to improved relations with external parties that are not customers, competitors or suppliers. Such external parties could for instance be regulatory authorities.

3.3.2.2 Resources of the business

The business value categories related to the resources of a business are divided into two categories; human resources and non-human resources.

Human resources

- *Decision making* refers to the ability to make faster and more correct decisions for instance by using a better decision support system.
- *Learning and knowledge* refer to improvements in learning and/or increased knowledge of people in the organization, for instance by making information more readily available.
- *Organizational culture* refers to the social and psychological situation in the organization.

Non-human resources

- *Information* refers to improvements in information availability and quality as experienced by the organization.
- *Technology/tools* refer to improvements in non-IT based tools and machinery used to produce products and/or services, by for instance improving production equipment.

3.3.2.3 Structure of the business organization

Opening up the black box, the business is viewed as consisting of a number of interrelated components and activities that are organized into a certain structure, such as for instance departments or processes. These components have general attributes which are reflected in a number of categories below. Another grouping of categories has to do with interrelations of components, and the final group of categories relates to the (change) management of the business organization.

Components of the business and their attributes

- *Strategy formulation and planning* refers to improvements in the ability to develop long-term business strategies and also to plan activities and projects.
- *Efficiency* refers to the ability to do as much as before with less resources, for instance by shortening process cycle times or reducing staff.
- *Productivity* refers to the ability to do more than before with the same amount of resources, for instance to produce more units with the same machinery.
- *Cost reductions* refer to the direct reduction of costs, for instance by using tele-conference system rather than having to pay for traveling for a meeting. (Worth noting is that all other categories some way or the other hopefully will have a financial impact on the business. This category is however reflecting the direct cost reductions that an information system can generate.

Connections between components

- *Communication* refers to improvements to the communication within or between processes or departments in the organization achieved through for instance more communication channels.
- *Flow of products/services* refers to improvements in the flow of products or services within or between processes or departments in the organization. This could for instance be achieved through improved flow of spare parts between departments.
- *Control and follow up* refers to the improved ability to control and follow up the organization's performance, for instance by introducing reporting possibilities.

Transforming and making changes to the structure

- *Change management* refers to the improved ability to change the organization, for instance by replacing people or roles.
- *Integration and coordination* refers to the ability to coordinate and integrate different parts of the organization, for instance by coordinating sales and production departments better.
- *Flexibility* refers to improved organizational ability to adapt to changes in market conditions/requirements due to for instance changes in regulations.

3.4 Linking technical properties to business value

This section discusses the principle used in the method for combining the results from the three frameworks described thus far. First, the business value impact from functions is described, followed by the business value impact from non-functional properties, and finally the business value prioritization.

3.4.3 Business value contribution from functionality

The purpose of this step is to identify which functional areas of the functional reference model that are linked with the business value dimensions, and to assess the strength of these links. Data is collected by interviewing current or future users of the information systems. The interview protocol is straight forward: For each business value dimension respondents are asked how much a specific functional area, contributes to specific business value dimensions. A question might thus be: *How much does system functionality Asset Investment Planning contribute directly to the business value dimension Inbound Logistics?* The answers are given on a scale from 0-4.

3.4.4 Business value contribution from non-functional properties

The business value impact from the information systems non-functional properties are calculated per functional area. Data is collected by interviewing potential users of the information systems working in the business. The interview protocol thus contains questions regarding the impact of a non-functional property the business value contributions of a specific functional area. An example question is: *How much impact does the fact that the system is Available have on the business value contribution from Asset Investment Planning?* The answers are given on a scale from 0-4.

3.4.5 Method for business value prioritization

Not all business value dimensions are of equal importance to the business. To capture this, a method for pair-wise comparison called the Analytical Hierarchical Process (AHP) (Saaty 1980) is utilized through the web-based tool FocalPoint (Telelogic 2006). AHP allows several respondents to make pair-wise comparisons of individual business value dimensions. The algorithm also offers the possibility to aggregate the results of rankings made by different respondents, and has a way of calculating the consistency of the results. See Figure 6 for a screenshot of the tool that was used for making pair-wise comparisons. The question posed to a respondent is: *Which business value dimension is in the long-term (more than 5 years) most important for the success of your business unit?* Respondents are presented with two different business value dimensions, and are then asked to compare them on a relative scale. The result from this step is a list with the relative weights of all business value dimensions. Suitable respondents for the prioritization are senior managers of the business unit in question.

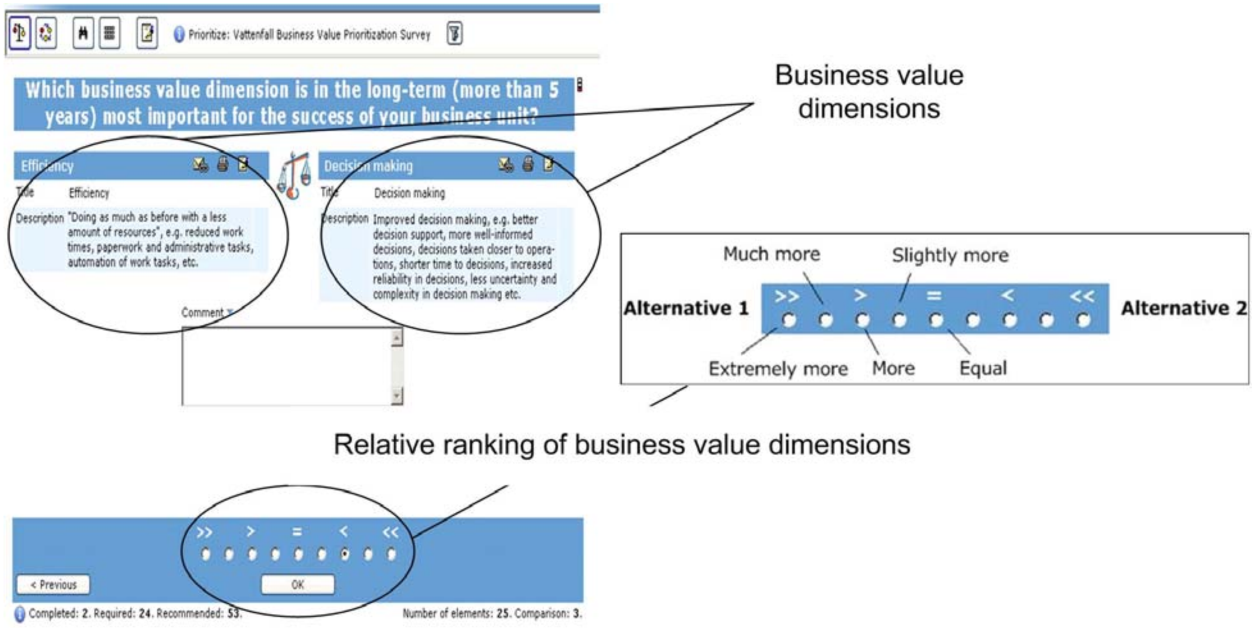

Figure 6: The user interface when doing pair-wise comparisons in FocalPoint (Telelogic 2006).

3.5 *Quantifying the method*

This section presents the mathematical foundation of the method. As mentioned in the introduction of this paper, a challenge for the method was to mediate the uncertainty of the data that is used in the method; there are more questions than there are answers and respondents answers might not be fully reliable. This section starts with a description of how the uncertainty of input data is estimated and then continues with describing the calculation mechanism used in the method.

3.5.1 Estimating the uncertainty of answers

To assess the uncertainty of each collected answer in the scenario evaluations, a set of *credibility heuristics* based on witness psychology and source criticism as employed in historical research were used (Edwardsson 1998) (Johansson and Johnson 2005b). These heuristics are (Gammelgård et al. 2007b):

- *Source Proximity*: The further away from the truth, the lower the certainty of the answers. If for instance a respondent has had personal experience with a system, answers from that respondent regarding that particular system are more credible compared to answers from another respondent who has only second-hand knowledge about the system.
- *Age of Answer:* This heuristic refers to when the respondent obtained the information in the answer.
- *Question Domain and Respondent Competence Domain:* This refers to the degree to which the respondent's general competence matches the subject domain of the question.

- *Match of Area of Expertise:* This dimension refers to if the respondent is correctly chosen. It differs from the previous dimension insofar as it refers to the credibility of the respondent per se, rather than the individual answers given by the respondent.
- *Years of Experience:* Refers to the number of years of experience the respondent has had in the relevant field of inquiry.
- *Respondent certainty:* Refers to the respondents' self-assessed credibility.
- *Interviewer's certainty assessment:* Refers to the interviewer's subjective estimation of the credibility of the answers.

As seen, the heuristics focus on the uncertainty of the answer and not the credibility of respondent per se. Although characteristics such as age of respondent, computer literacy etc. might have an impact on the answer these are not explicitly addressed but are an implicit part of the two last heuristics above. The is to both limit the heuristics to a reasonably number but also that the purpose is to assess the credibility of particular answer.

These properties were all quantified using a scale from 0 to 4, were 4 denotes the highest degree of certainty. For each answer the values of the seven heuristics were added linearly, thus obtaining a value between 0 and 28. A certainty index was then calculated as the ratio between the obtained certainty value and the highest possible value (28).

3.5.2 Calculating the aggregated business value of the systems scenarios

In order to aggregate all the individual pieces of information, including their certainty index, into high-level results, a Multiple Attribute Decision Analysis (MADA) approach is used for the technical assessment. Specifically, the evidential reasoning algorithm presented in (Yang and Xu 2002a) (Yang and Xu 2002b), which is an elaboration of the evidence combination rule of Dempster-Shafer theory (Dempster 1968) (Shafer 1976), was employed. This algorithm features the ability to aggregate uncertain, contradictory and incomplete answers without getting a bias towards a predefined distribution, which is the case for other statistical approaches. This is useful since it provides the ability to incorporate the uncertainty assessments of the answers, described in the previous section, as well as contradictory and incomplete answers. Figure 7 shows a conceptual view of the MADA assessments, where a value of a general property is calculated based on the assessment of one of the N basic attributes, each of which has an associated weight, ω. To illustrate that answers from respondents are often contradictory and uncertain, this assessment is based on contradictory answers from two respondents; respondent A believes that the answer is ”1” and respondent B believes that it is “2”, and neither one of the respondents are certain of their statements. The uncertainty value in the answer is calculated as 1 minus the certainty index of the individual answer, described in the previous section.

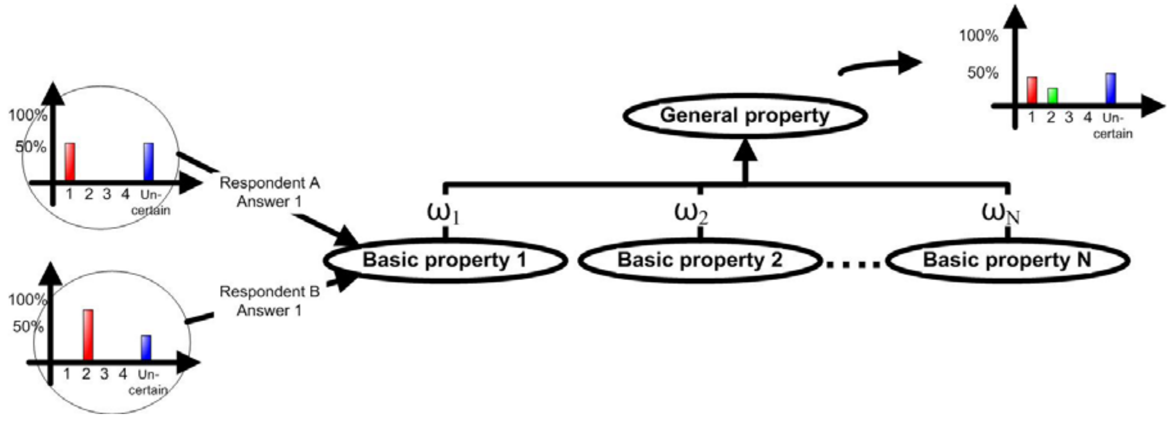

Figure 7: A conceptual view of how the aggregation of results was made in this study.

The process of calculating the business value of information systems scenario factors in three components. Firstly, the priorities of the business value dimensions. Secondly, the strength of the links between functional and non-function attributes and the business value dimension needs to be taken into account. Finally, the figures from the technical assessment of the information systems scenario is factored in, i.e. the functional and non-functional evaluations. The aggregation of these properties is outlined in Figure 8. The total business value is the aggregation of the business value in the previously described business value dimensions. Each of the 25 business value dimensions has been assigned a weight, $\omega_{BV,H}$ (where H=1,2…25), based on the prioritization described above.

The contribution to the business value from the technical properties comes from both functional and non-functional properties. Firstly, each function is related to a (set of) business value dimension(s). Secondly the non-functional properties of a system 'X' which implements function 'Y' with a coupling to business value dimension 'Z', is aggregated together with the value of the actual functional fulfillment of 'Y'. In mathematical terms these couplings are expressed as the weighting factors in the attribute aggregation. The weights of the links between the functions to the business value dimensions are denoted, $\omega_{FQC,\,I}$ where I=1,2…M (M is the number of links between the function and the business value dimension). The weights for the non-functional property impact on the strength of the business value contribution from the functions are denoted $\omega_{Q,G}$ (where G=1,2…7 - representing the seven different non-functional properties).

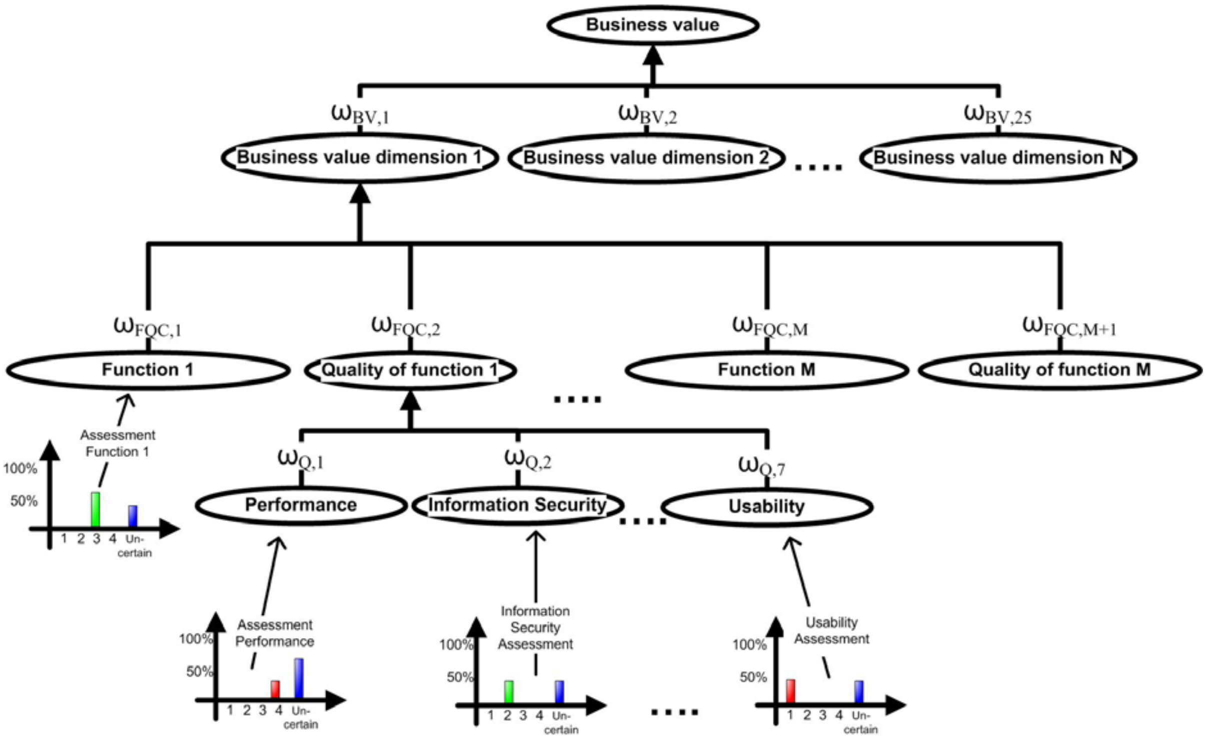

Figure 8: Principle used for the calculation of the business value of the information system scenarios.

When it comes to the uncertainties, the MADA approach manages the uncertainty of the input data, but not the uncertainties of the weights. To take this into account, standard Monte-Carlo simulations (Robert & Casella, 2004) using best and worst case-scenarios for the values of the weights may be employed. Hence by applying the Monte-Carlo simulation on the weights in the MADA approach the full uncertainty (stability) of the results are derived. That is since also the uncertainty of the data used to derive the weights also are included.

4. Configuring the method for application

Before the method is ready to use, some parts needs to be adapted to the situation at hand. Starting on the technical part, the functional framework needs to be tailored to suit the functional area that is to be assessed. Since the method is aimed at discerning which scenario provides the most business value it only concerns the relative business value impact of the scenarios. The scope of the functional reference model is therefore limited to the functional areas where the scenarios differ with respect to which system implements which functions.

It is time-saving to base the development of the functional reference model on existing models. However, there is no universal functional reference model covering all business domains. Several information system vendors e.g. (SAP AG 2008) have reference models for their respective system domains. Using vendor reference models will, however, introduce a bias into the evaluation towards products from that particular vendor. Such bias is of course unsatisfactory. Vendor neutral functional reference models may be available from standard bodies, trade organizations, etc. As an example of one of the more general and wide-spanning reference models the Federal Enterprise Architecture and in particular the Service Component Reference Model (OMB 2006) can be mentioned, another example is Scheer's process reference model (Scheer 1994).

Having found a functional reference model as a base, the development then proceeds to interview various stakeholders within the organization to validate the model with respect to three criteria: correctness – capturing the actual functional requirements of the business domain and the organization where the evaluation will take place, completeness – that no important functional descriptions are lacking, granularity – that the functional description's level of detail are suitable for the purpose of functional evaluations. See also (Gammelgård 2006b) and (Närman, 2006).

Also, the non-functional property framework needs to be adapted. The framework presented in Figure 4 above has a general structure suitable for most information system evaluations, but the metrics used to assess these general properties must be adapted to suit the system at hand. The example used in the case study presented here is presented in Chapter 5.

The tailoring process follows the following principles (Gammelgård et al. 2007a):
There must not be too many questions. The number of questions that can be asked are dependent on the resources available in the evaluation project; how much time and money the organization is willing to spend on the evaluation.

Only aspects that differ between systems scenarios are investigated. The aim of the method is to find differences between scenarios and enable a decision maker to find the best scenario. Therefore, metrics which values will be the same for all scenarios are excluded.

The questions should be as representative as possible. When reducing the non-functional framework according to the two previous principles it is important that the remaining questions still give an accurate and representative picture of the system. If there is little time to do the assessment it is important that the questions used do not focus on obscure and technology-specific issues. Rather than focusing on in-depth questions it is better to raise the level of abstraction and make sure that the questions are complete on a higher level of abstraction. For instance, it is better to ask a general question about the security of a system than ask one question about the system's firewalls.

Direct measures are preferred over indirect measures. Direct measures use a few parameters and the definition of a concept. For instance, system availability may be defined as the ratio between a system's uptime divided by the total time of operation (Hawkins and Piedad 2000). Direct measures require historical statistics about the system's operation which is only possible if the system has been in operation for some time. Since the evaluated system may not have been implemented, such operations data is not always available. In these cases the method relies on indirect measures. Indirect measures are factors that causally influence the evaluated properties. For instance, the existence and quality of a system's intrusion detection applications will causally influence the IT security of the system, and can be used as a sort of indirect security measure.

The business value framework is business domain neutral and does not need to be configured. However, since the framework is quite comprehensive it might be necessary to group the values into larger compounds to make it efficient. Either a selection of business value dimensions can be done by the evaluator before the business value prioritization but with the risk of excluding important dimensions from the business value dimensions. This can be avoided if the business value prioritization is done as the first step in the application of the method. Usually only handful of the 25 dimensions are relevant for the particular assessment at hand and the less important dimensions can then be excluded in the further steps of the method e.g. when linking functions to business value dimensions. This will considerably reduce the effort needed to complete the rest of the assessment but at the same time ensuring that the important aspects of the business value are considered.

Finally, the mathematical foundation of the assessment aggregation mechanism based on the Dempster-Schafer theory and is generally applicable, as is the algorithm used for estimating the credibility of the input data (Johansson and Johnson 2005a).

5. Industrial case study

The method was, as mentioned, applied in a case study at a large North European power company. The intention was to investigate which of three different system scenarios that would contribute with the most business value to the asset management process of an electricity distribution unit within the power company.

5.1 Scenario presentation

The potential future system architecture were summarized in three different scenarios: Scenario 1, which is the present situation based on a best-of-breed asset management system, labeled system A; Scenario 2, which is based on an upgraded version of system A; and Scenario 3, which is based on a system (system B) from the same vendor as the ERP system presently used. Table 1 presents the relative distribution of functionality between the systems and other systems of the scenarios as well as the total number of systems per scenario. Fortunately for the assessment process, all systems of the scenarios were present within different parts of the company.

Table 1. Characteristics of the three potential future scenarios.

	System A	**System B**	**Other systems**	**Total number of systems per scenario**
Scenario 1	38%	18%	44%	14
Scenario 2	45%	19%	35%	12
Scenario 3	0%	59%	41%	8

5.2 The functional assessment

The functional framework for the asset management functionality for the power company in question is based on the IEC 61968-1 for utility inter-application integration (IEC 2003). The original reference model was refined in a process (see chapter 4) which involved 26 experts from the Power Company and external vendors. The resulting reference model consisted of 5 functional areas comprising 11 functions which in turn were broken down into 53 sub-functions, see Figure 9 and (Närman 2006).

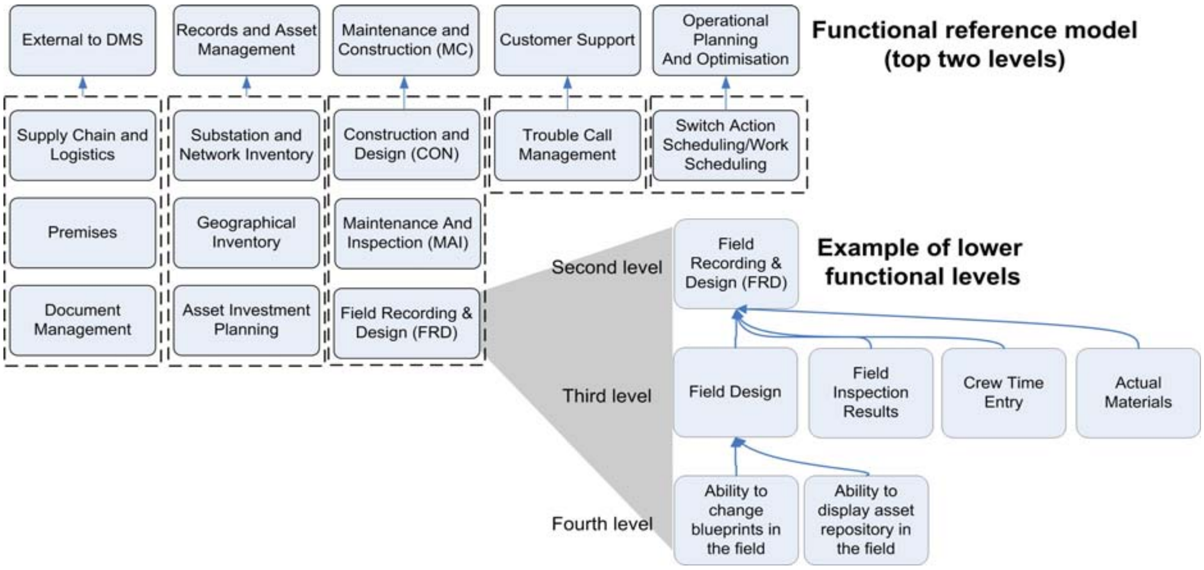

Figure 9: An overview of the functional reference model (Närman 2006).

The functional assessment of the scenarios was done by interviewing of users with experience with the systems of the scenarios. Assessments were made on a scale from ‘0’ to ‘4’. Details of the functional assessment are summarized in Table 2. The results for the 11 functions are presented in Figure 10 and the total functional fulfilment is found in Figure 11. Scenario 3 is slightly better than scenario 2 and scenario 1.

Table 2: Overview of the functional assessment.

	Scenario 1	Scenario 2	Scenario 3
Number of respondents	8	10	14
Number of answers	36	63	79
Number of functions to evaluate	53	53	53
Number of functions evaluated	31	31	46
Coverage of all functions evaluated	58%	58%	87%

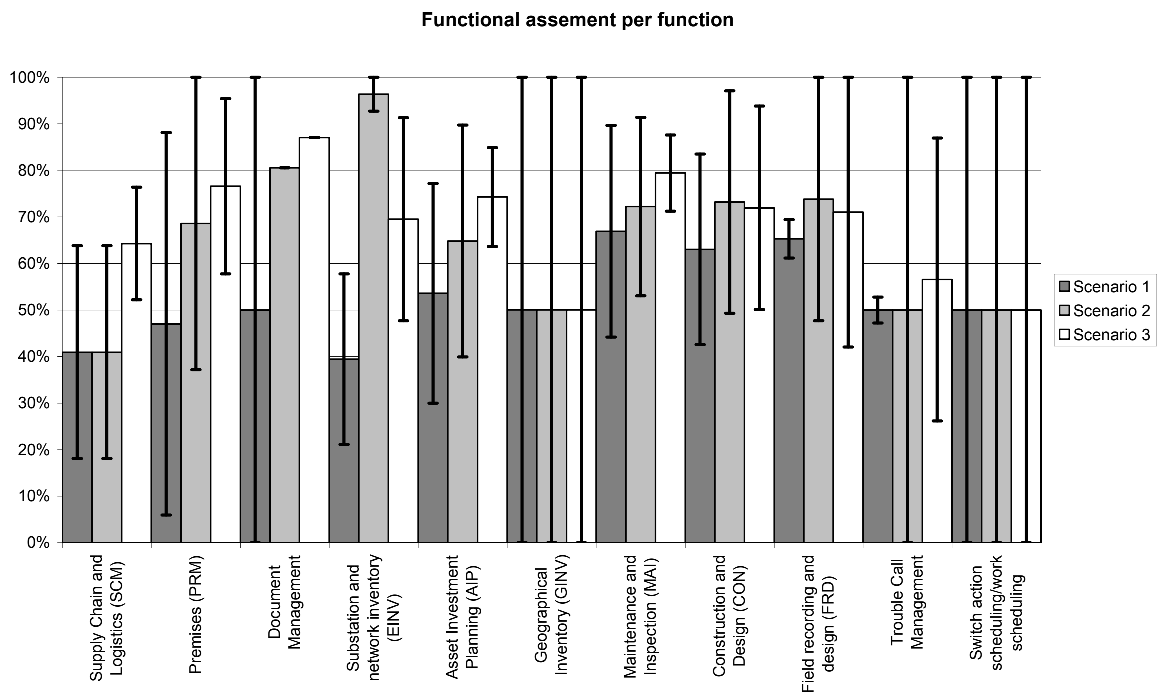

Figure 10. The assessment of the functional areas. The black bars indicate the uncertainty of the results. Some functional areas were not assessed in a few scenarios, e.g. “trouble call management” was not assessed in scenario 2, which results in 100% uncertainty.

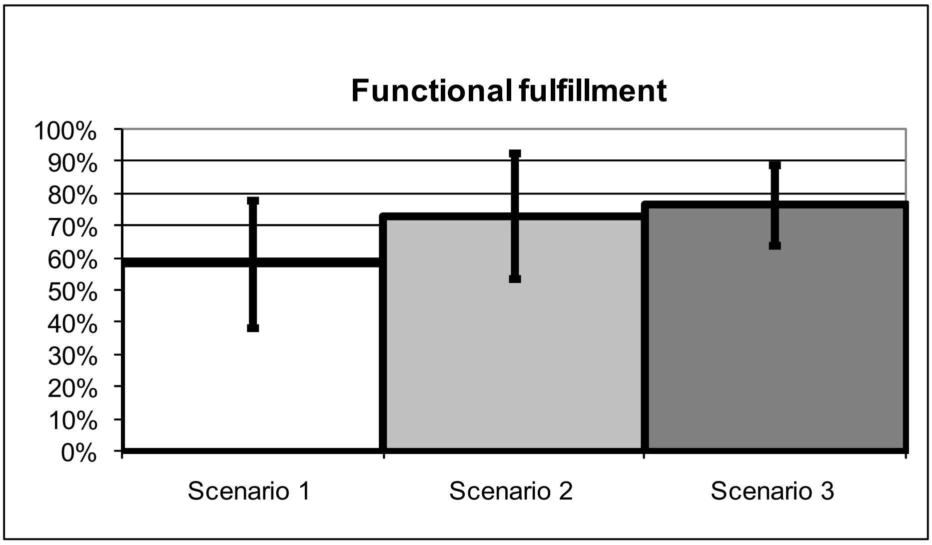

Figure 11: The functional fulfillment for the three scenarios. The black bars indicate the uncertainty.

5.3 The non-functional assessment

The non-functional property assessment framework was reduced according to the principles introduced in chapter 4 above. The framework is presented in Table 3 below.

Table 3: The non-functional property assessment framework, features 48 questions altogether. The references were used when developing the framework.

Quality attribute	**Operationalized Question**
Availability & Reliability [Direct measures] (Hawkins et. al. 2000)	What is the mean time to failure?
	What is the mean time to repair?
Data Quality [Direct measures] (Redman 2001)	How high is the data model’s contents quality? (I.e. the entities relevance, obtainability, clarity of definition, comprehensiveness, essentialness, and level of detail.)
	How high is the data model’s composition quality? (I.e. its naturalness, identifyability of items, homogeneity, consistency, and minimal redundancy.)
	How high is the data model’s ability to react to changes? (I.e. its robustness and flexibility.)
	How high is the data value quality? (I.e. the data values accuracy, completeness, currency, and value consistency.)
	How high is the data representation quality? (I.e. interpretability, portability, format quality, and consistency in representation.)
Information Security [Indirect measures] (Alberts 2001), (ISO/IEC 2000), (Swanson 2001)	To what extent are critical data and parts of the systems scenario separated from less critical?
	To what extent are users authenticated when using the system and to what extent are there separations between different users authority?
	How much of the information and communication is encrypted?
	How advanced are the firewalls and other measures protecting the system?
	To what extent are intrusion detection tools installed?
	To what extent is sensitive information monitored for unauthorized access or tampering?
	When a major system failure due to a security breach has occurred, how fast is the system back in normal operations?

Interoperability [Indirect measures] (Brownsword 2004),. (Linthicum 2000), (Tolk 2003),	For a larger integrations project, how much internal resources are normally available?
	For a larger integrations project, how much external resources are normally available?
	How skilled, knowledgeable and experienced are the available resources, both external and internal, in a larger integrations project?
	How structured is the integration/interoperability process in the systems scenario?
	How much technical integration facilitators, such as middleware and RPC, are present?
	How much standard protocols/integration mechanisms exits in comparison to the number of non-standard?
	Are standard integration mechanisms used?
	How much can be accessed via the standard protocols, i.e. how much of the functions and data can be accessed via standard protocols between the internal components?
	What is the complexity of the systems scenario's software architecture?
	How much documentation exists relevant to interoperability, e.g. interface documentation?
	What is the quality of the system documentation, with e.g. respect to availability?
Modifiability [Indirect measures] (Oskarsson 1982), (Berns 1984), (Bengtsson 2000), (Gefen and Schneberger 1996)	For a larger systems scenario change project, how much internal resources are available?
	For a larger systems scenario change project, how much external resources are available?
	How skilled, knowledgeable and experienced are the available resources, both external and internal, in a larger systems scenario change project?
	In a larger systems scenario change, how few components/modules/sub-systems in the scenario are affected?
	How many standard protocols/interfaces exist in comparison to the number of non-standard?
	How much standard are the internal integration mechanisms? I.e. how widespread are the standards?
	How much can be accessed via the standard protocols, i.e. how much of the functions and data can be accessed via the standards between the internal components?
	How structured is the change request process related to the systems scenario?
	How much documentation exists relevant to modification, e.g. design specification?
	How high is the quality of the system documentation, with e.g. respect to availability or traceability?
Performance [Direct measures] (Krishanswamy and Scherson 2000), (Deanro et. al. 2004)	What is the average time to perform operations using the system?
	What is the average time to before the system responds to an input?
	To what extent can the systems run on normal machines and still function properly?
	How many users can the system accommodate?
Usability [Direct measures] (Nielsen 1993)	Do you consider it easy to learn how to use the system in your work tasks?
	Do you consider it easy to learn how to use the system when you receive new work tasks?
	Do you experience that you can complete the tasks in the system efficiently?
	Do you consider it easy to remember how to use different parts of the system?
	When not having used the system for some time do you consider it easy to figure out how to use it in order to conduct your work task?
	Of all the errors and problems in your work tasks where you use the system, how much is the results of problems and errors in the system itself?
	Do you often experience problems when using the system?
	In general, are you satisfied with using the system in your work tasks?

Using the non-functional questions of the framework described above for an assessment of every system in the respective scenario was considered too time-consuming. In the end only systems A and B, which constitute the bulk of the system support for all three scenarios, were assessed. The drawback of this was a higher degree of uncertainty in the results. The questions were answered on a scale from '0' to '4'. The respondents were mostly system experts from the IT organization rather than system users, with the exception of the usability evaluation where system users were questioned. All in all, some 10 focused interviews lasting approximately 14 hours were performed. Details of the assessment are summarized in Table 4. Results of the assessment are presented in Figure 12.

Table 4: Overview of the non-functional assessment

	System A	System B
Number of respondents	5	8
Number of answers	73	195
Number of quality questions	48	48
Number of quality questions measured	44	48
Coverage of all questions	94%	100%

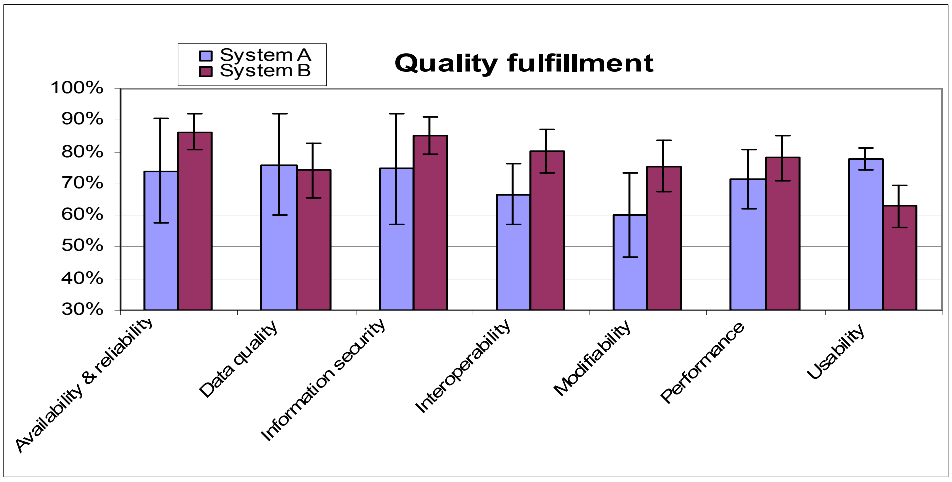

Figure 12. The aggregated non-functional properties of the two main systems of the scenarios.

5.4 Business value prioritization

10 respondents participated in the business value prioritization. The respondents were managers from various departments within the business unit. The surveys took approximately 20 minutes per respondent to finish and the response rate was 100 %. Three answers were discarded due to inconsistent answers. The result from the prioritization is presented in Figure 13.

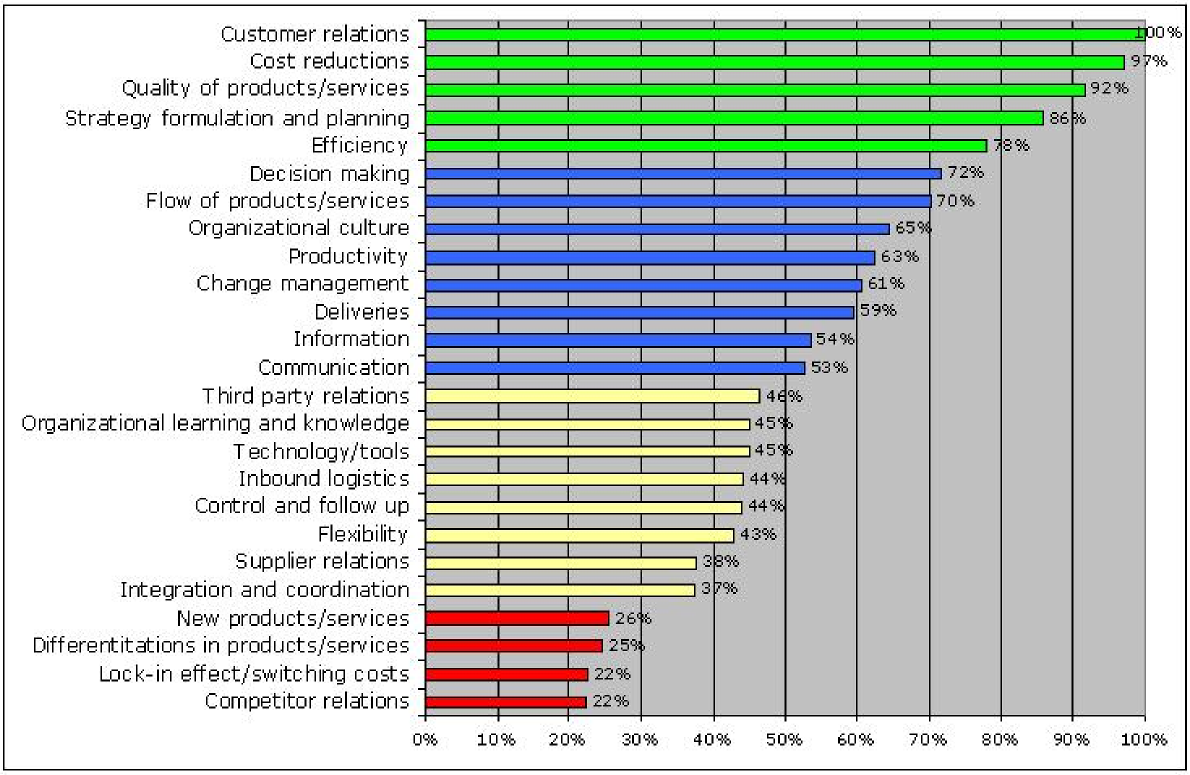

Figure 13. The relative importance of the business value dimensions.

5.5 Relating technical properties and business values

The coupling weight, $\omega_{FQC,\ I}$, from the functional assessment framework to the business values were assessed by interviewing system users. Figure 14 presents an excerpt of the resulting couplings.

		Function					
	Prioritization of business value dimensions	Asset Investment Planning (AIP)		Construction and Design (CON)		Maintenance and Inspection (MAI)	
Business Value Dimension		Value	+/-	Value	+/-	Value	+/-
Customer relations	100%	2.1	0.10	1.9	0.12	0.4	0.10
Cost reductions	97%	1.6	0.11	1.3	0.12	3.0	0.11
Efficiency	78%	2.0	0.11	0.9	0.12	3.1	0.10
Decision making	72%	3.7	0.08	3.9	0.04	3.8	0.02
Information	54%	2.8	0.08	2.7	0.09	2.9	0.11
Technology/tools	45%	0.3	0.10	0.0	0.09	0.0	0.08
Inbound logistics	44%	0.9	0.10	0.9	0.11	1.3	0.10
Control and follow up	44%	2.1	0.10	3.2	0.11	3.4	0.10
Supplier relations	38%	0.3	0.10	1.4	0.12	2.0	0.10
New products/services	26%	0.0	0.08	0.2	0.11	0.0	0.08
Differentitations in products/services	25%	2.4	0.11	0.3	0.11	0.7	0.11
Lock-in effect/switching costs	22%	0.0	0.08	0.0	0.09	0.0	0.08
Competitor relations	22%	0.3	0.10	0.0	0.09	0.3	0.09

Figure 14 An excerpt of the results of the couplings between functions and the business value dimensions. The column "Value" represents the average $\omega_{FQC, I}$ of all respondents' answers. The column labeled "+/-" shows the uncertainty associated with the strength of the coupling.

This information can be visualized in many ways. Figure 15 shows the aggregated business value per function and Figure 16 show the (linearly) aggregated functional support for each business value.

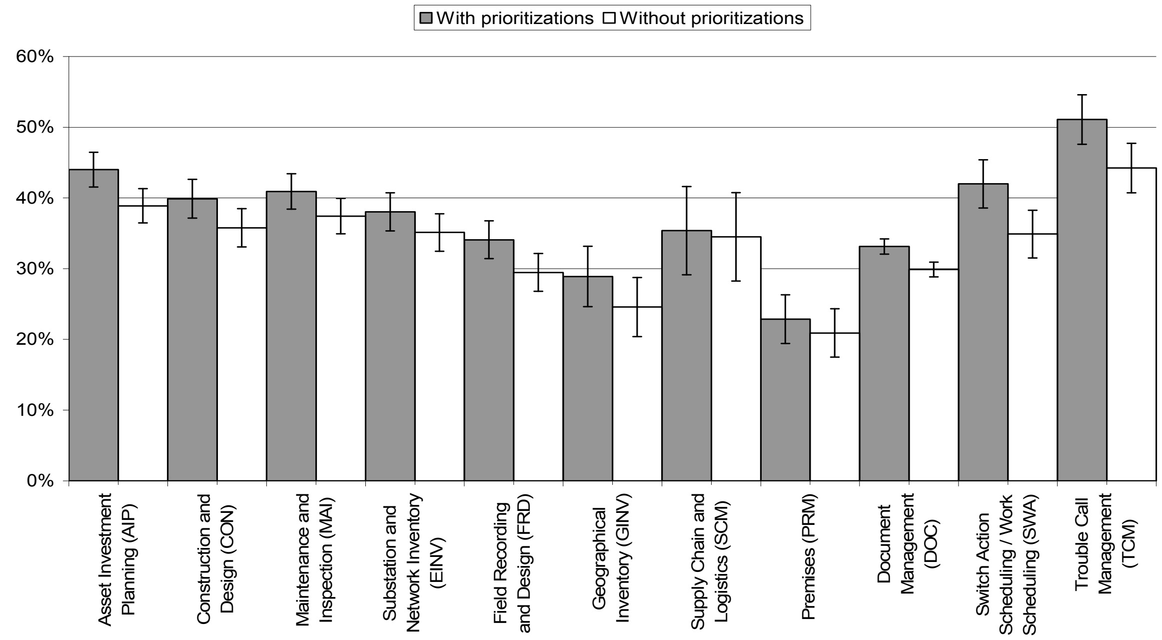

Figure 15. Aggregated business value per function, with and without prioritization of business value taken into account. 100% represents that the coupling between a function and each of the 25 business value dimensions is consistently rated "4".

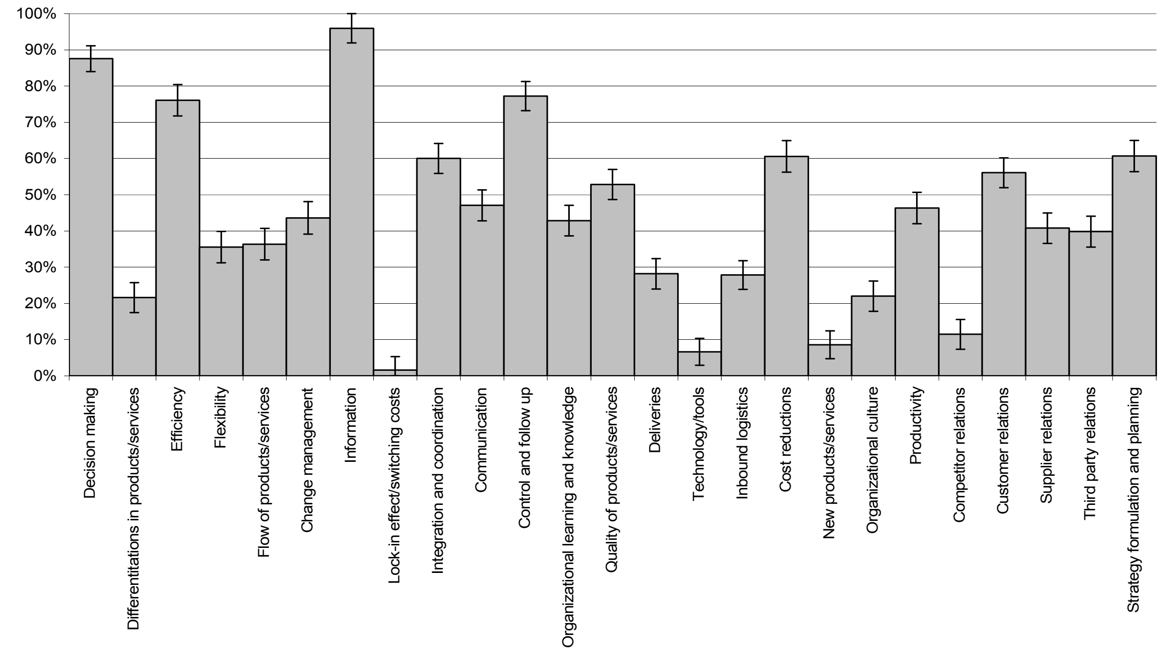

Figure 16. Aggregated functional support for per business value.

[

In a similar fashion the coupling of the non-functional attributes and the business value dimension is presented in Figure 17.

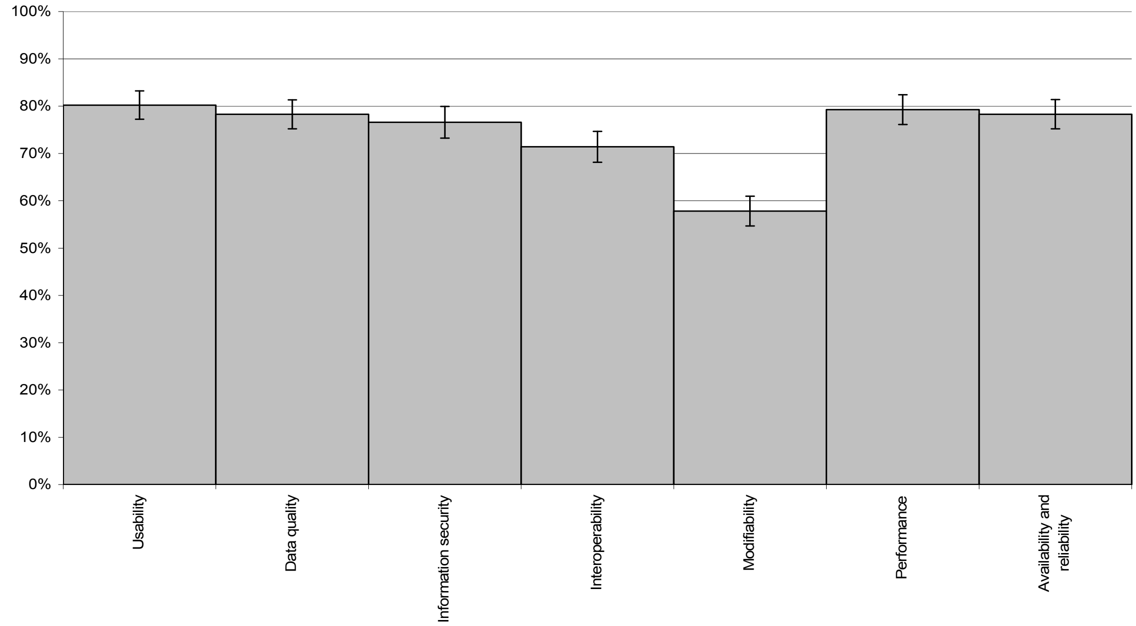

Figure 17. Aggregated business value per non-functional property without prioritization of business value taken into account. The results are aggregated for all functions for each non-functional attribute. 100 % implies that the quality's implication on the relations between the function and the business value dimensions is a "4".

5.6 Final results

Finally, all the intermediate results were aggregated into one estimate of business value contribution for the three scenarios. As seen in Figure 18, scenarios 2 and 3 appear to provide a higher business value than does scenario 1. On the highest level of analysis the result from the method is that scenario 2 or 3 is preferable. Even though there is a small numerical favor for scenario 3, this should not be interpreted as substantial favor for this scenario. Rather there should be other considerations that are taken into account for the final decision on scenario choice such as the cost (which is not at all considered by this method).The systematic and hierarchic nature of the method presented here provides excellent traceability thereby making it possible to make more in-depth analyses. For instance, the method may answer which are the strengths and weakness of each scenario? Are strengths and weaknesses evenly distributed over the functional areas and non-functional properties or are there specific weak/strong points? For a more elaborate analysis the reader is referred to (Gammelgård 2007b). Moreover it is worth mentioning that the comparison between the scenarios is fair in the sense that the uncertainties of the results are of the same order of magnitude. From this one might conclude that even though more time would be spent collecting data for the assessment the ordering of the scenarios would probably not change.

Although the aggregated business values of the three scenarios of course are specific for the particular application of the method, parts of the intermediate results can be generalized beyond the particular case. This is further described in e.g. (Gammelgård 2006), (Gammelgård 2007a), and (Närman 2006) For instance, the non-functional assessments of System A and B the results may give an indication of the non-functional qualities of the systems both for other business units in the company but also for asset management within other companies or industries. The degree of applicability of course depends on the degree of similarity to the asset management process in the case study.

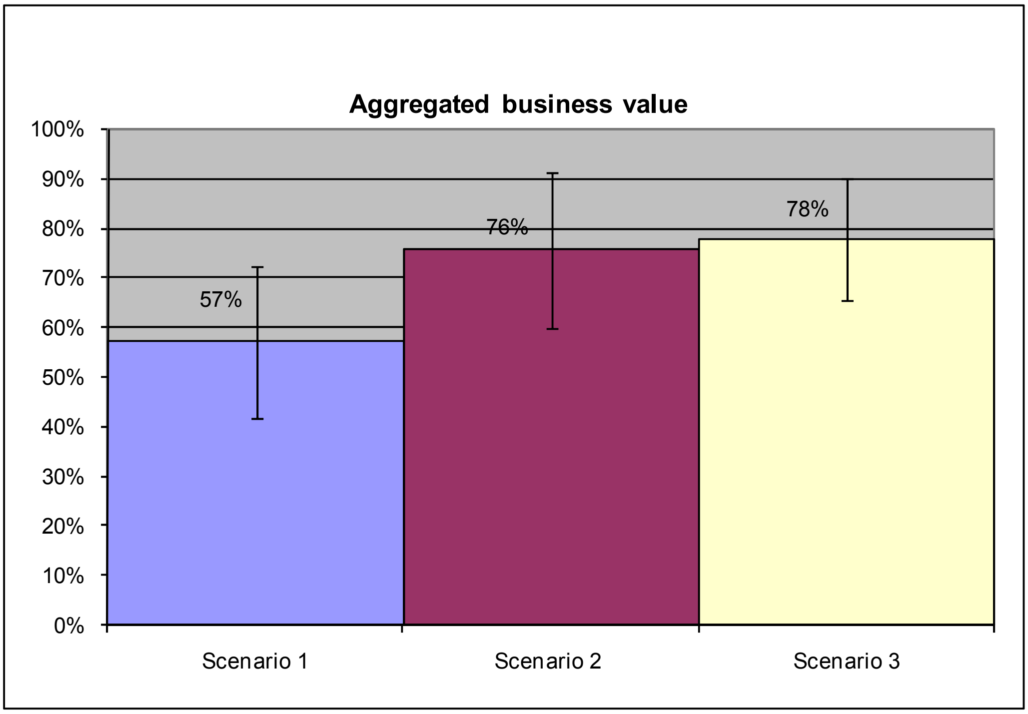

Figure 18: The final result of the business value evaluation for the three scenarios.

5.7 Industrial feedback

Having tested this method at several cases at the large power company mentioned above, the industrial feedback was mostly positive. The feedback has been received both from management as well as systems users at the company. Since it is method to provide better decision support the majority of the feedback has of course been from the decision makers. However, systems users has also expressed positive opinions particularly around the second point below, i.e. communication and the resulting enhanced transparency and understanding of reasons behind decisions.

Firstly the method is cost-efficient. Assessing three scenarios required approximately 45 hours of interviews (excluding the development of the method) When considering that the method is to be used to produce decision support before an investment decision concerning several million dollars and a complex asset management system with massive implications on business operations, the time and money spent is not unreasonable.

Secondly, theoretically based frameworks as the functional reference model, the business value dimension framework and the non-functional evaluation framework are powerful vehicles of communication. Frameworks such as these, once accepted within an organization, facilitate discussions in the sense that less time is spent trying to define what is meant by basic concepts. Previous information system choices in the organization have frequently been haunted by highly political arguments where different organizational units strongly advocated the use of whatever system they already operated. Having a structure to lean on reduced tensions between organizational stakeholders and focused the decision making process: Before, stakeholders had no choice but to express their opinion about a scenario as a whole, the method made it possible to express views on a much lower level of abstraction regarding for instance which business values that were of importance to the organization.

Thirdly, several of the separate parts of the method have been used for other purposes than the primary, i.e. to evaluate business value contribution from information system investments. For instance, the prioritization of the business value dimensions were used to illustrate and debate different business units' strategic directions. Another example is the functional reference model, which provided a basis for the requirements specification based on which the future scenario will be acquired.

6. Further works

Two separate research projects have been initiated to further improve the current structure, one project focusing on how to evaluate the technical properties of information systems; the PERDAF project (Närman et al 2007), and the other is focused on how information systems influence the business (Gustafsson 2007). Together these two projects are as comprehensive as the present method but offer two major advantages: Firstly: Both use a model-based approach and create architectural models based on the collected data. Using models not only favors comprehension of the evaluated information systems, it also makes information easily reusable. Secondly, instead of using the Dempster-Schafer mathematics for the statistical analysis of data, the evaluation frameworks in these projects are both using Bayesian Networks (Jensen 2001) which are more versatile mathematical tools. A richer account of the Bayesian network approach can be found in (Johnson and Ekstedt 2007).

7. References

Alberts, J. A., OCTAVESM Catalog of Practices, Version 2.0, CMU/SEI-2001-TR, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, October 2001

Ballantine, J.A., Stray, S., "Information systems and other capital investments: evaluation practices compared", Logistics Information Management, Vol. 12, No. 1/2, 1999.

Bannister F, Remenyi D, "Acts of faith: instinct, value and IT investment decisions", Journal of Information Technology 15:3 231-241, 2000

Bengtsson P.O., "Analyzing Software Architectures for Modifiability, Research Report 11/11", Department of Software Engineering and Computer Science, University of Karlskrona/Ronneby, 2000

Berns G., "Assessing Software Maintainability", Reports and Articles, Communications of the ACM, Vol 27, No 1, January 1984

Bertling, L (2002), "Reliability Centred Maintenance for Electric Power Distribution Systems", Doctoral thesis, Royal Institute of Technology, Stockholm, Sweden,

Brownsword, L., Current Perspectives on Interoperability, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, 2004

Dempster, A.P., "A generalization of Bayesian inference". Journal of the Royal Statistical Society, Series B 30 205-247, 1968

Denaro G., Polini A., Emmerich W., "Early Performance Testing of Distributed Software Applications", ACM SIGSOFT Software Engineering Notes, Vol. 29, Issue 1, January 2004

Edvardsson B. "The need for critical thinking in evaluation of information: criteria, principles and responsibility", 18th International Conference on Critical Thinking, Rohnert Park, USA, 1998

Gefen, D., Schneberger, “The Non-homogenous Maintenance Periods: A Case Study of Software Modification”, International Conference on Software Maintenance (ICSM ’96), Monterey, USA, 1996

Gammelgård M, Ekstedt M, Gustafsson P, “A Categorization of Benefits From IS/IT Investments”, Proceedings of the 13th European Conference on IT Evaluation (ECITE), 2006a

Gammelgård M, Närman P, Ekstedt M, Nordström L, “Business Value Evaluation of IT Systems: Developing a Functional Reference Model”, In Proceedings at the Conference on Systems Engineering Research (CSER), 2006b

Gammelgård M., Ekstedt M., Närman P., “Architecture Scenario Analysis – Estimating the Credibility of the Results”, In proceedings of the 17th International Symposium of the International Council on Systems Engineering, INCOSE 2007a

Gammelgård M., Ekstedt M, Närman P., ” Evaluation of business value of IT-system scenarios – a case study at a large north European power company”, Proceedings of the Portland International Center for Management of Engineering and Technology conference. (PICMET), 2007b

Gustafsson, P., “Evaluating IT Benefits Through Modelling the Organization”, Proceedings of the ECIME conference, 2007

Hawkins M., Piedad F., High Availability: Design, Techniques and Processes, Prentice Hall, 2000

IEC Technical Committee 57, Working Group 14, “IEC 61968-1 Application integration at electric utilities – System Interfaces for distribution management Part 1: Interface Architecture and General Requirements”, International Electrotechnical Committee, 2003

Jensen, F. V., Bayesian Networks and Decision Graphs, Springer Verlag, 2001

Johansson, E., Johnson P., “Assessment of Enterprise Information Security – Estimating the Credibility of the Results”, Proceeding of the Symposium on Requirements Engineering for Information Security (SREIS) in the 13th International IEEE Requirements Engineering Conference, Paris, France, 2005a

Johansson E., Johnson P., “Assessment of Enterprise Information Security – The Importance of Prioritization, In proceedings of the 9th IEEE International Annual Enterprise Distributed Object Computing Conference, Enschede, The Netherlands, 2005b.

Johnson P., Ekstedt M., Enterprise Architecture: Models and Analyses for Information Systems Decision Making, Studentlitteratur, 2007

Joint Technical Subcomittee ISO/IEC JTC 1, Information technology, Subcommittee SC 27, IT Security techniques, ISO/IEC International Standard 17799:2000 Code of practice for information security management, ISO/IEC, 2000.

Kazman R, Klein M., Clements P. ATAM: Method for Architecture Evaluation. CMU/SEI-2000-TR-004, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, 2000

Kotonya, G., Sommerville I., Requirements Engineering: Processes and Techniques, John Wiley and Sons, 1998

Krishanswamy U., Scherson I., “Framework for Computer Performance Evaluation Using Benchmark Sets” IEEE Transactions on Computers, Vol. 49, No 12, December 2000

Lindström Å, Gammelgård M, Simonsson M, "A method to assess the enterprise-wide IT resources for performance and investment justification", In Proceedings of the Conference on Systems Engineering Research (CSER), 2005

Linthicum D, Enterprise application integration, Addison-Wesley, New Jersey, 2000

Meyerson, B., "Using a balanced scorecard framework to leverage the value delivered by IS", Information Technology Evaluation Methods & Management, van Grembergen V., Eds., Idea Group Publishing, 2001

Morton K, "Asset management in the electricity supply industry", Power Engineering Journal october 1999

Nielsen, J., Usability Engineering, Morgan Kaufmann Publishers Inc., San Francisco, CA, 1993

Närman P., "A Functional Reference Model For Work and Maintenance Applications Within Asset Management at Vattenfall", Master Thesis, Department of Industrial Information and Control Systems, Royal Institute of Technology (KTH), Sweden, 2006

Närman, P., Johnson, P., Nordström, L., "Enterprise Architecture: A Framework Supporting System Quality Analysis", Proceedings of the EDOC-conference, 2007

(OMB) - Office of Management and Budget, "Federal Enterprise Architecture (FEA) Consolidated Reference Model Document Version 2.1", 2006

Oskarsson, Ö., Mechanisms of Modifiability in Large Software Systems, Doctoral Thesis Software Systems Research Center, ISBN 91-7372-527-7, Diss. 39081, Linköping University, Sweden, 1982

Pressman, R., Ince D., Software Engineering: A Practitioner's Approach, European Adaptation, 5th Edition, McGraw-Hill, 2000

Redman, T., Data Quality: The Field Guide, Digital Press, 2001

Reich BH, Nelson KM, "In Their Own Words: CIO Visions About the Future In-House IT Organizations", The Database for Advances in Information Systems 34:4, 2003

Robert CP, Casella G, "Monte Carlo statistical methods", Springer, 2005

SAP AG, "SAP Business Maps:Solution Maps", from http://www.sap.com/solutions/businessmaps/solutionmaps/index.epx, accessed 2008-01-31

Saaty T. L., The Analytic Hierarchy Process. Pittsburgh, PA: Univ. Pittsburgh, 1988.

Scheer, A.W., Business Process Engineering: Reference Models for Industrial Enterprises, Springer-Verlag, 1994

Schniederjans, M.J., Hamaker, J.L., "A new strategic information technology investment model", Management Decision, 41/1, 2003.

Shafer, G., A Mathematical Theory of Evidence. Princeton University Press, 1976

Strassman, P.A. Information Payoff, Free Press, 1985

Swanson M., "Security Self-Assessment Guide for Information Technology Systems", NIST Special Publication 800-26, National Institute of Standards and Technology, 2001.

Telelogic AB, Focal Point Product Information, [Online], Available: http://www.focalpoint.se [14 June 2006].

Tolk, A., "Beyond Technical Interoperability – Introducing a Reference Model for Measures of Merit for Coalition Interoperability",8th International Command and Control Research and Technology Symposium, Washington, 2003

Trigeorgis, L., Real Options: Managerial Flexibility and Strategy in Resource Allocation, MIT Press, 1997.

Wallnau K, Hissan S, Seacord R, "Building Systems From Commercial Components", Addison Wesley, 2002

Yang, J., Xu, D., "Nonlinear Information Aggregation via Evidential Reasoning in Multiattribute Decision Analysis Under Uncertainty", IEEE transactions on Systems, Man and Cybernetics, May 2002, p. 376, 2002

Yang, J., Xu, D., "On the Evidential Reasoning Algorithm for Multiple Attribute Decision Analysis Under Uncertainty", IEEE transactions on Systems Man and Cybernetics, May 2002, p. 289, 2002b

View publication stats