SCENARIO-BASED EVALUATION OF ENTERPRISE ARCHITECTURE

A top-down approach for chief information officer decision making

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Abstract: As the primary stakeholder for the Enterprise Architecture, the Chief Information Officer (CIO) is responsible for the evolution of the enterprise IT system. An important part of the CIO role is therefore to make decisions about strategic and complex IT matters. This paper presents a cost effective and scenario-based approach for providing the CIO with an accurate basis for decision making. Scenarios are analyzed and compared against each other by using a number of problem-specific easily measured system properties identified in literature. In order to test the usefulness of the approach, a case study has been carried out. A CIO needed guidance on how to assign functionality and data within four overlapping systems. The results are quantifiable and can be presented graphically, thus providing a cost-efficient and easily understood basis for decision making. The study shows that the scenario-based approach can make complex Enterprise Architecture decisions understandable for CIOs and other business-orientated stakeholders

1 INTRODUCTION

Historically, business operations of large companies were supported by a number of isolated software systems performing diverse specific tasks, from real-time process control to administrative functions. Today, many companies possess a truly complex enterprise IT system; in large organizations thousands of interconnected systems may be employed.

Typically, the emerging enterprise IT system has not evolved through a careful and holistically planned approach, rather each business unit has developed and acquired the IT systems they need. The system support provided may very well be optimal to the individual business units, but for the enterprise as a whole it can results in higher costs and lower quality. A poorly planned (or non-existent) overall architecture is the harbinger of hard times to come; problems with inconsistencies will become inevitable as the IT systems become increasingly wild-grown (Bracket, 1994), (Linthicum 2000), (Mc Govern 2003), (Ruh 2001), Zachman, 1987).

One example of this is *overlap*, meaning that similar functionality can be found within different systems and that multiple versions of the same data are stored within the enterprise IT system. An increased functionality and data overlap leads to higher costs for operation and maintenance, because of the larger number of systems and databases (Land, 2003). For data overlap, the master/slave dilemma is one central aspect. It can be hard to find original (master) data among the multiple versions (masters or slaves) stored in numerous places deep inside the system jungle. Inconsistent naming of data is another common issue; the same piece of data may have many different names within the enterprise IT system, and different data sometimes are given the same name (Bracket, 1994) (Mc Govern 2003), (Ruh 2001), (CIO Council, 1999).

To complicate the situation further, general knowledge of the systems within the enterprise is often quite poor. The IT systems are known on a superficial level, but there is a lack of overview regarding how the systems are interconnected, which protocols are employed, how the functionality is allocated, etc. In-depth information does exist on individual systems, but the knowledge is scattered among individuals.

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1.1 Decision Making for the Chief Information Officer

As responsible for the enterprise IT system, the role of the Chief Information Officer (CIO) covers a broad technical and organizational scope, including areas such as IT-business alignment (Brown, 1993) (Cassidy, 1998) (Gottschalk, 1999), IT investment decisions (The Open Group, 2004), IT system quality assessment and improvement (Kirkpatrick 2002). All these issues may result in architectural changes (Brown, 1993) (Cassidy, 1998) (Gottshalk, 1999) (Spewak, 1992).

There are plenty of questions that the CIO needs to answer in order to make decisions. These include, for instance, what IT system supports a particular business process, what are the possibilities for system consolidation, what is the current security level, how will a new system affect the system complexity, etc.

The difficulties in finding relevant information described in the previous section makes decision-making a complicated task. Since the CIO constantly lacks time, it is necessary that decisions can be made quickly and to a small cost. Ad hoc decisions without direct linking to a uniform IT strategy should, however, be avoided. Rather, all decisions should be based on a consistent IT strategy to ensure a cost-efficient enterprise IT system (Brown, 1993) (Cassidy, 1998) (Gottshalk, 1999).

Finding adequate information for decision-making is however often quite problematic, since the CIO rarely has all the information needed at hand. The information is spread throughout different sources within the enterprise. In order for the CIO to make correct decisions, support is needed to identify, gather and evaluate this scattered information. Enterprise Architecture Frameworks, specifically developed to serve as a controlling blueprint for the enterprise IT system, has been proposed as such support (CIO Council, 2001) (Clinger-Cohen Act, 1996).

1.2 Enterprise Architecture Frameworks

In order to understand and manage the chaotic real world of enterprise IT systems, as well as support the identification, gathering and evaluation of the scattered information needed for decision making, the discipline of Enterprise Architecture has emerged. It has emerged from the need for taking a holistic approach to IT-system management. This means that the discipline focuses on not only the technical aspects but also on the organizational context in which the IT systems operate. Enterprise Architecting is thus both a technical and an organizational undertaking (CIO Council, 1999) (DoD, 2003) (The open Group, 2003) (Spewak, 1992) (Zachman, 1987).

Enterprise Architecture is a model-based management and planning approach for the evolution of enterprise IT systems; it has been proposed mainly as a response to the ever-increasing significance and complexity of business-supporting information systems (CIO Council, 1999) (DoD, 2003) (The open Group, 2003) (Spewak, 1992) (Zachman, 1987).

The methods and models of Enterprise Architecture are often presented in frameworks. Today there exist ten or so well-known architectural frameworks for management of enterprise IT systems (CIO Council, 1999) (DoD, 2003) (The open Group, 2003) (Spewak, 1992) (Zachman, 1987).

However, current Enterprise Architecture Frameworks, propose that a plethora of models should be developed and maintained. However, it is rarely evident when and why a particular model is to be preferred over others and what questions they are created to answer. By trying to cover all aspects of Enterprise Architecture, contemporary frameworks get too extensive and are therefore difficult to penetrate in search for relevant information. When it comes down to hands-on support for decision making, the current frameworks fall short and information gathering becomes a time-consuming and costly issue. This is unfortunate since a model should be able to answer specific questions.

2 A SCENARIO-BASED APPROACH FOR DECISION MAKING

As discussed previously, the existing Enterprise Architecture Frameworks have a different focus and fall short in providing decision-support to the CIO (Lindström 2005). In order to be cost effective, the approach must be goal oriented, i.e. start with what is to be decided upon, and gather relevant information to support the decision making. By questioning the CIO about the information needed to make a specific decision, a structured gathering of relevant architectural information can be made. The CIO should continuously work towards adhering to the overall IT strategy; therefore the CIO decision making can be viewed as a problem of selecting the solution that has the highest degree of fulfilment towards the IT strategy.

The scenario-based approach for CIO decision making outlined here (and used in the case study described in Chapter 3) was originally described by Johnson, and consists of three steps described in sections 2.1 to 2.3 (Johnson, 2004). The power of the approach lies in its use of hypothetical (what-if) situations, i.e. scenarios, which implies that the CIO can play with different ideas without suffering the cost of actually implementing all solutions. By using scenarios, the decision-maker and other stakeholders can discuss possible solutions, their strengths and weaknesses, in a way understandable for all stakeholders. On a conceptual level, the approach mimics the scenario-based Architecture Tradeoff Analysis Method (ATAM), described by Kazman in (Kazman, 1998). The approach used here differs from the ATAM by considering the Enterprise Architecture as the object of study and by using a prioritization technique for trade off analysis. In comparison, the ATAM approach focuses on the architecture of one single IT system.

2.1 Formulation of scenarios

Firstly, the CIO needs to consider what possible solutions are available with respect to the future structure of the enterprise IT system and the problem at hand. The scenarios must be well delimitated and easy to separate in order to be understandable and analyzable for all stakeholders. These hypothetical solutions, *scenarios*, are formulated in images and text to give an easily understood overview of possible solutions to present problems. In ATAM, the word *architectural option* is used in line with the ATAM approach, where scenarios are elicited from stakeholders of the system (Kazman, 1998), scenarios for the Enterprise Architecture are elicited from stakeholders of the entire Enterprise Architecture. The scenarios serve both for describing possible future states of the architecture, as well as facilitating communication among stakeholders and analysts of the architecture.

2.2 Identification of evaluation criteria and indicators

The next step is to identify relevant criteria and measurable indicators for evaluation of the scenarios. A good evaluation criterion provides answers to the questions of the CIO; the more important questions it answers, the better it is. In order to be more concrete indicators must be employed. Indicators are measurable properties such as number of systems or a yes or no answer. As the real world is complex, multiple evaluation criteria and indicators can be found for each decision. The relation between the criteria and the indicator is called architectural theory and can be simple rules of thumb or more strict and precise presumptions.

Using IT-security as an example, one architectural theory is that a system with a firewall has higher security than one without. In this case, high IT-security is the criteria, and an indicator might be simply counting the number of systems not protected by a firewall.

Again conceptually similar to the ATAM approach, where system requirements are used as criteria, the approach proposed here relies on criteria or architectural theory to evaluate the architecture. Though, the scenario-based approach differs in the scope of the criteria. In ATAM, the requirements are relatively detailed, while the criteria proposed here are more in line with the indicators used in e.g. Balanced Score Card approaches (Kaplan, 1996), used to evaluate business strategies and measure business performance.

2.3 Analysis and selection of scenarios

Analysis is the application of evaluation criteria and indicators on scenarios for evaluation purposes. Usually only a subset of the available criteria and indicators are analyzed, since using all of them is a time consuming task for the CIO.

The selection of indicators is based on how much effort must be spent on finding the needed information, the usefulness of the indicator, the relevance for the CIO and the credibility of the theory issuing party (Johnson, 2004).

Furthermore, because of company policies and goals, some criteria are more important than others. Therefore, the CIO is given the opportunity to prioritize among the criteria, which results in weighted criteria. Another reason for the prioritization is to manage trade offs between contradicting criteria. The prioritization of evaluation criteria and choice of indicators are two of the major advantages with the scenario-based approach.

For the prioritization, a web-based tool for prioritizing requirements is proposed since it is easy to use. The prioritization technique is built on AHP (Karlsson, 1998). The prioritization tool picks two criteria and lets the respondent perform a pair-wise comparison. Each criterion is compared multiple times. A nine-grade scale is used for the prioritization, and results in a prioritization ladder with the respective weight of each criterion represented as a fraction of 100 %.

Different *views*, showing only a subset of the indicators, are employed in order to simplify the analysis. A system-activity view, for example, illustrates the alignment between IT systems and business process activities.

The indicators are applied on and measured for each scenario. In order to be able to compare the different indicators, the measures are normalized.

Each scenario is presented to the CIO along with the measurements performed at it, thus serving as basis for a discussion on the results of the architectural analysis. Finally, the CIO may select one of the scenarios to be implemented.

3 APPLICABILITY TESTING: CASE STUDY

A case study was carried out to test the general applicability of the scenario-based approach described in the section above. Empirical data was collected from one of the largest electric utilities in Europe, with an annual turnover of $14.5 billion (2003). According to CIOs at the utility, 350 major software systems are employed in order to run core processes and administrative functions.

An increased integration of formerly stand-alone systems over the past decade and acquisition of new systems has resulted in a likewise augmented occurrence of overlap in terms of functionality and data. The main focus of the case study is thus a matter of defining how functionality and data should be allocated between existing systems. There are, of course, numerous solutions to this problem, which entails the necessity of a proper analysis basis for choosing the most adequate solution.

This case comprises four main systems in the service process, which manages repairs and extensions of the power distribution grid. The systems are the Enterprise Resource Planning system (ERP), the Distribution Management System (DMS), the combined Network Information System and Geographical Information system (NIS/GIS) and the Customer Information System (CIS). All these systems, except for the CIS, provide some amount of unique functionality, but also overlap in that some functionality is shared between two or more systems. See Figure 1.

The case study was conducted as collaborative work between the individuals within the CIO function at the utility and the authors.

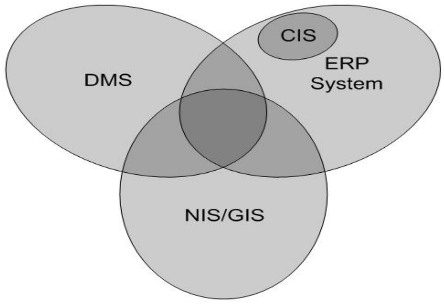

Figure 1: The overlap dilemma

3.1 Formulation of scenarios

The systems involved in the current service process were studied to obtain an understanding of the situation. A total of 37 activities were identified within the process. About 35% of these were affected by an overlap. It was found that the main overlap exists between the ERP System and the DMS. These two can, independently, control the workflow of the process apart from a few specific activities. The ERP System and the DMS are, however, not completely replaceable. No matter which one is chosen to supervise the process; the other system is still needed to perform certain tasks. Furthermore, an overlap in managing customer related data and asset data were identified. The first can be located in either one of the CIS or ERP systems whilst the latter can be stored in the NIS/GIS or in the ERP system. To summarize, the overlap dilemma for the service process at the electric utility comprises an *overlap in the process workflow* and an *overlap in managing customer and asset data*.

Six scenarios for the automation of the service process were found. Simplified illustrations for the system-data view for two of the scenarios are presented in this paper; see Figure 2 and Figure 3. The main difference between these two scenarios is that the system in control of the workflow (as in managing the flow of information between different entities) varies. Figure 2 shows a scenario where the DMS is in control of the workflow. All four main systems, the CIS included, are employed to run the process. In the ERP System scenario depicted in Figure 3, the ERP System manages the workflow. Just three software systems are employed for running the process. The CIS is removed and all customer related data is incorporated into the CS module of the ERP system.

Please observe that the total amount of modules is not constant between the two scenarios. This is due to the fact that when the ERP System takes control over the workflow, some modules become obsolete, and vice versa.

3.2 Identification of evaluation criteria and indicators

As stated, the approach outlined here is conceptually similar to other scenario-based architectural evaluation methods, e.g. ATAM (Kazman, 1998). However, when evaluating entire Enterprise Architectures, quality attributes used in such methods, fall short in providing a sound basis for evaluation. Other criteria and architectural theory must be found as well, due to the broader scope. Finding the architectural theory is the work of researchers since the credibility of the theory issuing part should be high.

As is the case for measures used in e.g. the Balanced Score Card, the indicators used in the scenario-based approach must be aligned with the strategic goals of the enterprise (Kaplan, 1996). The CIO can therefore evaluate the scenarios based on their fulfilment of the corporate IT strategy. For the case study on allocation of functionality and data across a number of IT systems, the indicators need only to reflect a subset of the entire corporate IT strategy.

The set of indicators used in the case study emanates from strategy fulfilment measures used by the CIOs at the studied utility and a compilation of indicators to judge function allocation taken from literature. The opinions of the CIOs, as knowledgeable stakeholders for the applied Enterprise Architecture, were stressed. When appropriate architectural theory was not found in literature, rules of thumb and common sense had to be applied to define measurable indicators.

For example, a suitable indicator for the Modifiability criterion is to measure the number of modules in a particular solution (Oskarsson, 1981). Again, for Complexity, a suitable measure is the number of systems and modules involved (Linthicum, 2000). Interestingly, as can be seen from the above, the indicators may require a tradeoff analysis since some may be contradictory. This latter point stresses the fact, that although evaluation criteria can be measured, the optimal solution to the problem will require more analysis than merely adding up the measures.

A set of nine criteria was used. Below is a short description of the criteria (**bold**) and indicators (*italic*) used in the case study. Please note that the same indicator might be used for measuring several criteria, as mentioned earlier in this section.

Architectural changes – The number of changes that are made to the original architecture. *The number of databases relocated* and *the number of systems added or removed* were used as indicators for measuring this criterion.

Accessibility of data – The ease with which the user can access the data. For the ease of access, data should be located as close to where it is needed as possible (CIO Council, 1999). The indicator used for measuring this was *the number of data transfers between systems needed on a per function basis*.

IT-Business alignment – How well the IT systems support the business processes (Cassidy, 1998) (CIO Council, 1999) (Luftman, 2000). Here, a rule of thumb is provided by (Luftman, 2000), who states that the more use of an ERP system, the better the alignment. The architectural guidelines of the electric utility equally advocate that functionality should preferably be implemented in the ERP system. The indicator used for measuring this was *the number of functions controlled by the ERP system.*

Efficiency – The CIO function defined efficiency as a low total dataflow between the systems. The indicator that was used in order to measure efficiency was *the number of data transfers between systems*.

Modifiability – The ease with which a system can be changed (internally). A system is considered modifiable if existing modules easily can be replaced and new ones can be added (Bass, 1998) (Kazman, 1998) (Oskarsson, 1981). Two indicators were used to measure the modifiability: *The number of modules per system* and *the number of standards that each software system supports*.

Quality of data – Quality of data is a broad term. To ensure that the data meets the businesses needs, it shall be accurate, complete, consistent, timely and flexible (Bracket, 1994) (Linthicum, 2000). The CIO function focused on *the number of data transfers needed to carry out the process* as an indicator for measuring quality of data.

Accuracy of data – All handling of data can result in decreased accuracy, since data might become corrupt during the conversions related to the handling (Boehm, 1978). Two different indicators were used to measure accuracy: *The number of times that databases have to be updated in order to run the process* and *the number of data transfers between systems needed on a per function basis.*

Scalability – The ability to grow/shrink the capacity/performance of a system according to the demand of the environment in which it operates. A scalable system should therefore be highly structured and comprise many fully separable modules (Kazman, 1998) (Linthicum, 2000) (The Open Group, 2003). The indicator used for measuring scalability was *the average number of modules per system*.

System complexity – A complex architecture is difficult to understand, verify and change. System complexity both refers to the software architecture and the environment in which it operates (Linthicum, 2000) (Zachman, 1987). Two indicators were used for measuring system complexity, *the number of systems involved in the process* and *the number of suppliers involved in realisation and support of the scenario.*

3.3 Analysis of scenarios

Each scenario was illustrated with a set of views, showing certain relationships between entities. As an example of how the views were employed in the case study, simplified versions of the system-data views for two of the scenarios are presented in Figure 2 and Figure 3. The views show relationships and data transfers between the systems and their modules respectively. Grey boxes represent the systems and white boxes symbolize lower-level system modules, i.e. Human Resources System, Graphical User Interface, and so on. The arrows illustrate data transfers, flow directions are indicated by the arrow heads.

Apart from the system-data view, a process-system view, showing relationships between process activities and systems, and a process-data view depicting relationships between activities and data flows, were applied for each of the six scenarios. These views are not necessary for showing the applicability of the approach and are therefore not presented in this paper.

An unweighted score, representing for example the number of modules or data connections in a certain view, the grade of fulfilment to a security policy, etc., was then obtained for each indicator, and the same score was used for the corresponding criterion. For instance, the number of systems employed in each scenario served as an indicator for measuring the system complexity criteria. As can be seen in the simplified Figure 2 and Figure 3, the ERP System scenario employs fewer systems than the DMS scenario and was therefore considered having less system complexity. Please note that the figures presented in this paper are extremely simplified and cannot be used for repeating the measurements with accurate results.

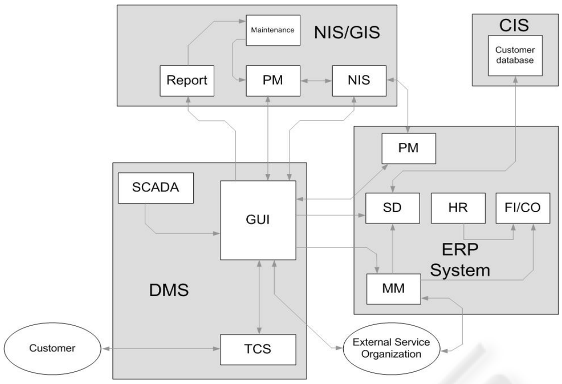

Figure 2: DMS scenario, DMS manages the workflow

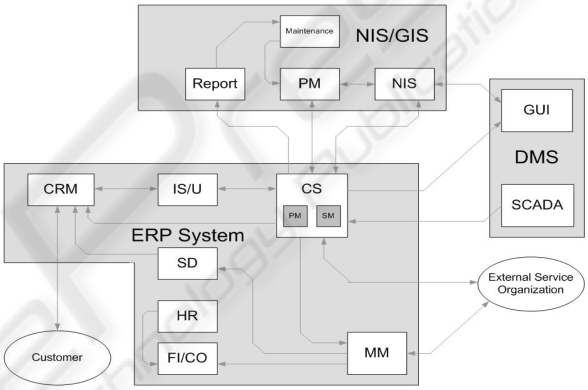

Figure 3: ERP System scenario, ERP System manages the workflow

In order to normalize the scores, the best scenario for each criterion was allotted 10 points. The other five were normalized against it, resulting in unweighted scores between 1 and 10 for each indicator and scenario. When multiple indicators were used for measuring a single criterion, average scores was calculated.

Prioritization of criteria was conducted with key personnel at the utility, aiming for an identification of the most important criteria, seen from the utility's point of view. The evaluation was tailored so that it would bring out the system qualities regarded as most vital. The participants were asked to weigh criteria in a pair-wise comparison. A prioritization ladder was then obtained with the respective weight of each criterion represented as a fraction of 100%.

A weighted score could be calculated by multiplying the score of a criterion by its respective weight. The *total weighted score* is the sum of the weighted score for all criteria in one scenario. It comprises the final result of the study.

3.4 Results

When studying the total unweighted scores only, it showed that the results varied with less than 15 percent between the six scenarios.

Table 1 shows the results for two of the scenarios. However, when looking at the unweighted scores for specific criteria, it showed that they varied heavily between scenarios.

Table 1: Prioritized criteria with unweighted and weighted scores for two scenarios

Criterion (Priority)	ERP System score (unweighted/ weighted)	DMS score (unweighted/ weighted)
Quality of Data (21%)	10 (210)	7 (147)
IT-Business Alignment (18%)	7,5 (135)	4 (72)
Accuracy of Data (15%)	10 (150)	8 (120)
Accessibility (11%)	10 (110)	8 (88)
Efficiency (9%)	10 (90)	8 (72)
Scalability (8%)	8 (64)	9 (72)
System complexity (8%)	9 (72)	8 (64)
Modifiability (7%)	8 (56)	8,5 (60)
Architectural changes (4%)	8.5 (34)	10 (40)
Total score:	**81 (921)**	**70,5 (735)**

All scenarios were individual and had distinctive strengths and weaknesses. It could also be concluded that each scenario did better on at least one criterion than any other. For example, the DMS scenario depicted in Figure 2 was generally better at modifiability and scalability (even though the differences were small), while the ERP System scenario depicted in Figure 3 did better on Quality of Data and IT-Business alignment. No scenario was without merit and therefore no clear winner could be identified by using the total unweighted scores only. The CIO inevitably should consider trading one quality for another in order to make a decision on which scenario is the better of the six.

The differences between the scenarios increased when the prioritization of the criteria was taken into account. As can be seen in Table 1, some criteria were deemed twice as important as others. Given the fact that Quality of Data, IT-Business alignment, Accuracy of Data, and Accessibility were considered the most important criteria, it was clear that the ERP System scenario by far exceeded the DMS scenario. The suggestion given to the utility was therefore to implement the former solution.

4 DISCUSSION AND CONCLUSIONS

To minimize the frequency of architectural ad-hoc decisions made by CIOs, tools are needed. Since many CIOs today serve as human fire extinguishers instead of having the strategic and proactive role they should, these tools must be sharp, easy to use and time saving. The contribution of this study is a well-defined approach to identify and evaluate possible solutions to any given Enterprise Architecture-related problem.

Today, the available tools include different Enterprise Architecture Frameworks, which are hard to apply in the real world because of their extensiveness. If the proposed top-down approach is used, the question that the CIO needs answers to do, together with a set of criteria, provide guidance for collecting adequate information. Merely a minimum of views, containing relevant information, are created and used for analysis purposes. The approach stresses that criteria should be prioritized and that only the most relevant criteria and indicators should be used. The aim is to have just enough information to make the right decision. This serves four purposes:

1. Less time is spent on searching for information that is not needed.
2. The general soundness of the architectural theory for the particular question, according to the CIO, is taken into account.
3. Tradeoffs between criteria are identified and evaluated.
4. The relative importance of each criterion will influence on which scenario that will be selected.

The case study showed that all scenarios were individual and had distinctive strengths and weaknesses. It could also be concluded that each scenario did better on at least one criterion than any other. It was thus a matter of trading off benefits and disadvantages arbitrary between the scenarios. Thus, the differences between the scenarios increased when the prioritization of the criteria was taken into account. Without a structured tradeoff between properties, a scenario that scores high on a property with low priority may receive he highest total score. After a consultation with CIOs at the utility, the scenario that best fitted the requirements was selected. In order to carry out a scenario-based evaluation of Enterprise Architecture with a reliable result, evaluation criteria must be taken from widely accepted sources. It is therefore a task for academia to provide the industry with general architectural theory.

The evaluation criteria used in the case study can be refined by digging deeper into literature. Relying on a solid base of theory from multiple and well-known sources, the evaluation criteria can be trusted. The case study also showed that finding indicators for measuring criteria can be quite hard. Rules of thumb and common sense had to be applied in certain cases.

The results, being quantifiable and illustrated, provide a search cost-efficient (using only relevant criteria for evaluation), high-quality (based on multiple and well known sources) and easily understood (explained at a high level of abstraction) basis for decision making. This was confirmed by interviewing several CIOs at the electric utility a few months after the original study was committed. They all agreed on the usefulness of the scenario-based approach, and the different scenarios served as a basis when deciding upon the future of their IT systems. According to the CIOs, an analysis could be made rapidly and in a structured manner. The views served well in explaining complex cross-dependencies between systems. The study shows that this scenario-based approach can make complex Enterprise Architecture decisions understandable for both CIOs and stakeholders with poor IT knowledge.

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