An e-Process Selection Model

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Abstract

A number of e-Processes (i.e. software processes for developing e-Commerce information systems) exist in industry. We presuppose that for a subclass of these their targeted quality is considered as a driving force of system development. The complexity of selecting a well-suited e-Process for a case at hand is thus increased as e-Process knowledge needs to be blended with system quality knowledge. We suggest an approach for selecting a best suited one out of a set of admissible e-Processes using the Analytic Hierarchy Process for knowledge blending and discuss how the data generated can be used for assuring the sensibility of the selection. We explain the AHP-based selection procedure, tradeoff- and sensitivity analysis; briefly discuss a case study and the applicability of this approach.

Keywords: ECIS, e-Process, e-commerce development, Analytic Hierarchy Process, multi-criteria decision making.

1 Introduction

We define Electronic Commerce Information System (ECIS) as an information system for accessing meta-information on goods, selecting and purchasing goods, including performing the actual payment and refer to software processes that are suited for the development of ECIS as e-Process (e-P). There are different types of ECIS, but we focus in this paper on business-to-customer (B2C). We consider B2C more vulnerable to not meeting the right perceived quality. B2C-users who are not satisfied with the perceived system quality might try using a different B2C and might not turn into customers. ECIS differs from conventional information systems in tending to have a high degree of both customer- and external system interaction, and require management of content quality and amount. Thus software processes do not necessarily qualifies as e-Ps.

According to Mansar, et al. (2005) the benefits from using project- and problem specific software processes are significant, and one should choose a suitable software process for optimizing the quality of a system under development (SUD). We quote from Brynjolfsson (2003) "IT has been the biggest single factor driving the productivity resurgence" and "IT creates value only if it lets users work more effectively". According to MacCormack, et.al. (2003) the "… problem is not so much that we lack 'silver bullets' for a project manager's arsenal but that we have such an extensive array of differently coloured bullets that choosing between them is very difficult." We still think that making a sensible choice is possible but when humans are performing this task, they need to be aided. This paper proposes such an aid.

In (Kaschek and Mayr, 1996, Kaschek and Mayr, 1998) frameworks were proposed for comparing object-oriented modeling tools and analysis methods. This was adapted for selecting from admissible business process modeling methodologies (Kaschek, et.al., 2006). We reuse and extend this paper's general approach. In (Albertyn and Kaschek, 2004, Albertyn and Zlatkin, 2004, Albertyn, 2005 and Albertyn and Kaschek, 2005) ontology for e-Ps has been used together with an ad-hoc approach to quantification based e-P selection. In (al-Humaidan and Rossiter, 2000) similar research regarding workflow-oriented information systems was done.

Paper outline. In section 2 we explain our model and then discuss a case study in section 3.

2 The selection model

We consider three quality aspects of a method for e-P selection as essential, namely economically viable, justifiable, and provide insight into the selection made. We achieve viability of our approach by relying on the expertise of those who, in a case at hand, have to make a selection. This includes admitting qualified individuals to play both expert roles that we employ in our method. If the experts consider the selection task as clear-cut and one of the admissible e-Ps as the obvious one to select then we recommend the project to just go ahead with that e-P. However, if the experts are not sure about the e-P to select then we recommend applying the Analytical Hierarchy Process (AHP) that is described below. AHP (Saaty, 1990) is a very well-known and successfully applied method for multi-criteria decision making. Obviously our selection task is an instance of that decision making task and thus justified.

Selecting one from a number of admissible e-Ps and providing insight into this selection is an instance of decision making and Simon's model of decision making has three stages - intelligence, design, and choice (Ahituv and Neumann, 1990). We focus on choice because we consider existing software processes only and presuppose, simplifying significantly, that the decision maker knows all existing software processes and knows how to identify the admissible ones. We suggest quantitative assessment for identifying top-scorers and then choosing one of them. The overall quality of e-Ps that we aim at expressing quantitatively is their suitability for developing an anticipated B2C. The method thus is SUD specific and its outcome not necessarily extendible to other cases.

In our attempt to quantify e-P quality we opt for assessment rather than measurement because we feel that soft and contextual factors need to be included that due to the attempt to achieve repeatability and independence from the measuring agent are excluded from what can impact the obtained quality score. In our method these soft and contextual factors of e-P quality are taken into account by the unrestricted capacity of the involved experts to recommend what appears as sensible to them.

2.1 System quality aspects and expert selection

Quality of e-Ps is multi-faceted (as is the case for information systems in general (Ghezzi, et.al., 2004). Individual quality aspects are often considered as too broad and unspecific and are therefore decomposed into lists of lower level quality aspects. We exploit the two-level hierarchy in (Kaschek, Pavlov, et. al., 2006). For our method the employed quality aspects are irrelevant, i.e., any other set could be chosen as well. However, the outcome of using our method is likely to critically depend on the chosen quality aspects. Due to our focus on illustrating our method we do not argue in particular for the chosen quality aspects and do not list the second level quality aspects employed:

- *e-P aspects*, i.e. the e-P's modeling notions, abstraction concepts, etc.;
- *quality concepts* of the e-P, i.e., its reliability, robustness etc.;
- *cost* for using the e-P;
- *domain impact*, i.e. the impact of the project domain;
- *usability*, i.e. the e-P's aid in developing a high quality B2C;
- *compatibility* of the e-P with other methodologies, and
- *maturity*, i.e. e-P's stability, tool support, documentation etc.

We suggest that the expertise required for our selection task is provided by humans in the role of e-P expert or system quality expert. The AHP enables us blending the experts' expertise to select the e-Ps best suited for the problem at hand. Choosing the experts is not necessarily trivial or cheap. We thus recommend considering the qualification profile of the designated developers. If that profile indicates sufficient e-P and system quality expertise then we recommend using these developers as experts. We also recommend admitting any individual for playing both expert roles if the required expertise is available. A somewhat more complicated approach to expert selection is described in (Kaschek, Pavlov, et. al., 2006). Expert modeling for expert selection likely is to consider affiliation, area of competence, standing, availability, price, etc. The AHP can also be used for choosing the experts. However, experts with expertise in expert selection might be hard to identify. According to (NUREG, 1989) expert selection should consider demonstrated experience, expert versatility, expert group diversity, and expert cooperation.

AHP-based selection proceeds in steps that we call *e-Process ranking*, *system quality aspect ranking*, and *knowledge blending*. Our method, after scoring the admissible e-Ps, proceeds with *tradeoff analysis* and *sensitivity analysis* on the data provided by applying the AHP. These two techniques make our method providing insight into the selection suggested.

2.2 e-Process ranking

The e-P experts rank the admissible e-Ps by pair-wise comparison in terms of the second-level quality aspects.

Let x, y be e-P. For expressing a number of increasingly strong preferences for x over y we define the predicate m-better(x, y), for $m \in \{1, 3, 5, 7, 9\}$. The predicate 1-better(x, y), 3-better(x, y), 5-better(x, y), 7-better(x, y), 9-better(x, y) means that no preference, light preference, moderate preference, strong preference, and extreme preference respectively is given to x over y. Let C^1, C^2 the first- and second level quality aspects respectively, $C = C^1 \cup C^2$, and for $c \in C^1$ let J_c be the set of second-level quality aspects into which c has been decomposed, i.e. $C^2 = \bigcup_{c \in C^1} J_c$, the disjoint union. Let furthermore be E a set of e-Process experts, and X a set of e-Processes. We use the predicate β(e, m, x, y, c) to denote that expert e judges m-better(x, y) = TRUE with respect to quality aspect c and define $a: C \times E \times X \times X \rightarrow \{m, 1/m \mid m \in \{1, 3, 5, 7, 9\}\}$ as a(c,e,x,y) = m, if β(e,m,x,y,c) and 1/m, if β(e,m,y,x,c). The mapping a is called comparison mapping. Obviously, a(c, e, x, y) = 1/a(c, e, y, x), and in particular a(c, e, x, x) = 1, for all $c \in C$, $e \in E$, $x, y \in X$. Let be $c \in C$ a quality aspect, $e \in E$ an expert, and for brevity X = {1, …, n}, then for the restriction A(c,e) of a to X × X holds A(c, e) (i, j) = a(c, e, i, j), for all i, j. We represent it as the pair-wise comparison matrix (Saaty, 1990). Its elements are the results of all pair-wise e-Process comparisons: $A(c,e) = (a(c,e,i,j))_{1 \leq i,j \leq n}$). If this matrix is consistent (i.e. a(c,e,i,k) · a(c,e,k,m) = a(c,e,i,m) for any i, k, and m), the maximum eigenvalue $\lambda_{\max}(c,e)$ of A(c,e) and the corresponding eigenvector $f(c,e) = (y_1, \ldots, y_n)$ are known. This vector, after normalization, contains the relative weights y_i of all e-Processes $i \in \{1, \ldots, n\}$. The relative weight of $x \in X$ following (Saaty, 1996) is denoted as $f_{c,e,x}$. We define $f: C \times E \times X \rightarrow [0, 1]$, with

$f(c, e, x) = f_{c,e,x}$ and use the geometric means for aggregating that various experts' findings into a score of x regarding c, i.e. $f_{c,x} = \sqrt[|E|]{\prod_{e \in E} f_{c,e,x}}$, with |E| being the cardinality of E. Software implemented by Roman Pavlov, Kharkiv enables us employing the simplified version of AHP described in (Noghin, 2004), where the pair-wise comparisons are reduced to the minimum needed for determining a consistent pair-wise comparison matrix. Defining a(c,e,i,j):= a(c,e,1,j) / a(c,e,1,i), for all $1 \leq i, j \leq n$ implies consistence. With $w_i = (1 / a(c,e,1,i)) / \Sigma_{j \in \{1, 2, \ldots, n\}} 1 / a(c,e,1,j)$ the relative weight for all i. Assigning the m-better predicate to pairs of e-Processes according to (Noghin, 2004) can be managed such that an arbitrary e-Process $x' \in X$ at first is chosen (we always assumed x'=1). Then $y \in X \backslash \{x'\}$ is chosen such that assigning the appropriate predicate m-better(x', y) becomes simplest. Then $z \in X \backslash \{x', y\}$ with the same property is chosen, and so forth until X is exhausted.

2.3 System quality aspect ranking

The system quality experts apply two times the pair-wise comparison technique for assessing the relative importance of the quality aspects in the case at hand. First the top-level aspects are ranked and then at the decompositions thereof. We thus obtain weights w^{**}_c, and $w^{*}_{c,j}$ for $c \in C^1$, and $j \in J_c$. For obtaining integrated weights for the second-level quality aspects we define w: $C^2 \rightarrow [0, 1]$, $j \mapsto w^{**}_c w^{*}_{c,j}$, for $c \in C^1$, $j \in J_c$.

2.4 Knowledge blending

For blending the available kinds of expertise we use the "ideal synthesis" AHP mode (Forman and Selly, 2001). For that we use the maximum value $f^*_c = \max \{f_{c,x} \mid x \in X\}$ for normalization, i.e., for $c \in C^2$, $x \in X$, we denote, as usual, the c-score $w_c f_{c,x} / f^*_c$ of x as $p_{c,x}$. The score p_x of $x \in X$ is then defined as $\sum_{c \in C^2} p_{c,x} \Big/ \sum_{x \in X} \sum_{c \in C^2} p_{c,x}$. The set of e-Ps best suited for the problem at hand is considered to be the set $\{x \in X \mid p_x = \max \{p_y \mid y \in X\}\}$. The restriction to a two level hierarchy of quality aspects is conventional. If necessary we could decompose further. For each additional nesting level we could aggregate a higher-level number out of the data available at that additional nesting level

2.5 Tradeoff analysis

After selecting the set of e-Ps best suited for the problem the next step is to provide insight into the selection made. First, to express preferences regarding quality aspect implied by employing a particular e-P, tradeoff analysis is performed. Consider a case of developing an ECIS and x, $y \in X$ be e-Ps. Adapting the approach in (Zhu, et. al., 2005) we define the tradeoff entailed by favoring x over y as the relinquishment of the top-scoring quality aspects of y that are not top-scoring for x. The purpose of the tradeoff analysis is the creation of awareness of the tradeoffs implied by employing a particular e-P.

We follow Zhu, et. al. (2005) in using tradeoff diagrams as a tool for tradeoff analysis. For each pair (c, d) of e-P quality aspects a tradeoff diagram is created. Each tradeoff diagram represents a part of the plane with c, d being represented as the abscissa and ordinate respectively. As maximum value for abscissa and ordinate the maximum value of any quality aspect weight is used in all these diagrams. In any tradeoff diagram each $x \in X$ is represented as a point $r(x) = (p_{c,x}, p_{d,x})$. In each of these diagrams the first quadrant is divided into four squares of equal size. For each pair $(c,d) \in C^2$ with $c \neq d$ this defines an equivalence relation e(c,d) on X with $(x,y) \in e(c,d)$ if r(x), r(y) lie in the same square. Denote the upper-left, lower-left, lower-right, and upper-right square as UL, LL, LR, UR respectively. Then favoring x over y entails favoring c over d and favoring d over c if r(x) lies in LR and UL respectively. No tradeoff is considered to occur if r(x) lies in LL or UR. However, x is considered as favoring c and d if r(x) lies in UR, and disfavoring c and d if r(x) lies in LL. An example of tradeoff diagram for four e-Ps is shown on Figure 1. On this diagram, selecting e-P(1) and e-P(2) entails favoring d over c, selecting e-P(4) – favoring c over d, selecting e-P(3) disfavors both quality aspects.

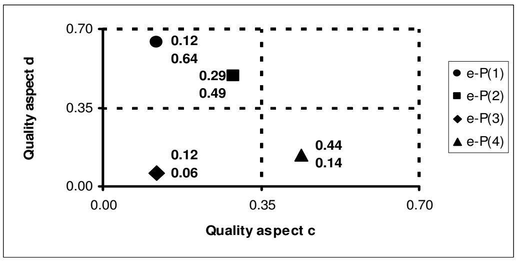

Figure 1: Tradeoff diagram example

We recommend calculating all tradeoff diagrams and considering those that indicate tradeoffs being entailed by selecting one of the top-scoring e-Ps. We recommend doing a more detailed analysis when any tradeoff diagram shows an odd tradeoff due to selecting a top-scoring e-P. A technique for a more detailed analysis is the following. Let $x \in X$ be top-scoring and c, $d \in C^2$ such that $r(x) \in UL$, i.e. a tradeoff of d over c occurs.[2] Then $p_{c,x} < p_{d,x}$. This is obviously in line with the expertise provided if $f_{c,x} < f_{d,x}$. We thus recommend to consider a tradeoff as not significant with respect to the selection task if $f_{c,x} < f_{d,x}$. If, however, the opposite inequality holds, i.e. $f_{c,x} \geq f_{d,x}$, then $\frac{w_c}{f^*_c} < \frac{w_d}{f^*_d}$.This inequality could result from two potential kinds of error. First, one could have wrongly ranked c or d too often second or first respectively in the pairwise comparison procedure. Second, one could have wrongly ranked x too often first with respect to c and too often second with respect to d. If checking these potential errors reproduces the result we consider the tradeoff as OK. Otherwise our method should be completed with the

[2] We restrict to $r(x) \in UL$ since our argument essentially extends to the case $r(x) \in LR$.

old data and revised new data obtained from repeated pairwise comparisons. If undesirable tradeoffs cannot be avoided and several top-scoring e-Ps exist we recommend using one that has the tradeoffs that seem to be most acceptable.

2.6 Sensitivity analysis

Sensitivity analysis indicates consequences of the potentially poor quality of the input data and identifies those quality aspects and e-Ps in terms of which the final ranking is most sensitive to changing data.

The input data, i.e., the pair-wise comparisons both of the e-Ps and the quality aspects are biased by the experts' subjective views and errors they might make. If one presupposes that the procedure, i.e., the AHP, itself is sound then the data quality is left over for assessment. We are suggesting conducting a respective sensitivity analysis and create a sensitivity diagram for each e-P quality aspect. The required calculations are performed by evaluating the formula for p_x by fixing all but one quality aspect and letting the latter vary in small steps in an interval I. We thus obtain the final score p_x for $x \in X$ and $c \in C$ as a function $p_{c,x}$: $I \rightarrow [0,1]$, with the restriction $p_{c,x}(v) = p_x$ for the score v of x regarding c. In our setting these functions $p_{c,x}$ are all linear. In the sensitivity diagram for quality aspect c we depict the function $p_{c,x}$ for all admissible $x \in X$. Additionally we indicate with a vertical line the c-score $p_{c,x}$ of a particular $x \in X$. An example sensitivity diagram for the quality aspect $c \in C$ and four e-Ps is depicted in Figure 2.

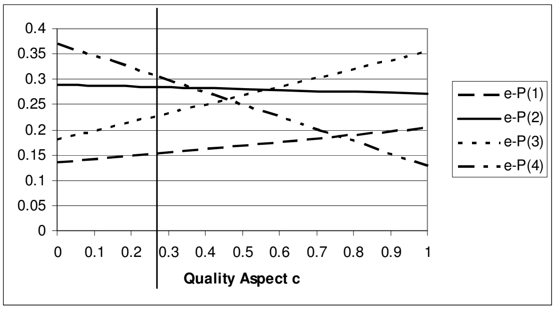

Figure 2: Sensitivity diagram example

Moving the vertical line horizontally signifies changing the c-scores of the admissible e-Ps. Approaching that way an intersection of any of the depicted functions' graphs means that a so-called rank reversal occurs if the quality aspect scores were changed accordingly. Such reversal can be unexpected because the AHP scoring procedure and the system of quality aspects both are complex.

As a result of the sensitivity analysis of the whole set of quality aspects and e-Ps (using the set of all possible sensitivity diagrams), the following sensitivity measures (Triantaphyllou and Sanchez, 1997) can be obtained and presented to the method users:

1. *Quality aspect criticality degree*. This measure, for $i \in \{1,2\}$, is calculated for every quality aspect $c \in C^i$. c's criticality degree is the minimal percentage of change of w(c) for any rank reversal to occur. The criticality degree can be calculated using the distance between the vertical line in the sensitivity diagram and the closest intersection of any e-P functions' graphs. In Figure 2, it is the distance to the intersection of the functions of e-P(2) and e-P(4). If no functions' graphs intersect on the diagram, this measure cannot be calculated, it is the case of *criticality degree infeasibility* indicating that no variations of the quality aspect's weight affect the ranking of e-Ps. Ranking quality aspects according to this degree lets the user observe the differences in their sensitivity to the data variations.

2. *Percent-any critical quality aspect*. This, for $i \in \{1,2\}$, is the quality aspect $c \in C^i$ with the smallest criticality degree among all the quality aspects at level i. This quality aspect can be considered as the most sensitive to the data variations. If no such aspect is found (for all $c \in C$ the criticality degrees are infeasible), the e-Ps ranking can be considered stable.

3. *Percent-top critical quality aspect*. This, for $i \in \{1,2\}$, is the quality aspect $c \in C^i$ with the smallest relative change of w(c) for any rank reversal to occur among the top-scoring e-Ps. This quality aspect can be considered as the most important for our selection task, because the variations of its weight most likely affect the selection outcome. If no such aspect is found, the selection outcome can be considered stable.

4. *E-Process aspect-related criticality degree*. For $x \in X$ and $c \in C$ this is the smallest amount by which w(c) needs to be changed to alter the ranking of x. It measures the influence of w(c) variations on the ranking of x. This criticality degree can be calculated using the distance between the vertical line and the closest intersection of the x's function graph and any other e-P function graph. On Figure 2, the criticality degree of e-P(3) is based on the distance to the intersection of its graph and the graph of e-P(4). This degree can also be infeasible if no variations of w(c) affect the ranking of x.

5. *E-Process criticality degree*. This is the smallest aspect-related criticality degree for the e-P $x \in X$. Ranking e-Ps according to this degree lets the user observe the differences in strength of their AHP-produced ranking.

6. *Most critical e-P*. These are the $x \in X$ with the smallest criticality degree. Each most-critical e-P is among the e-Ps for which the ranking is most unclear and weak. In fact, the ranking of most critical e-Ps should be investigated further. If no most critical e-P can be found (for all $x \in X$ the criticality degrees are infeasible) it also indicates the stability of AHP-produced ranking. If the top-ranking e-Ps all are most critical the whole selection process has likely to be revised because this fact signifies that the outcome of this process is not reliable and sensitive to smallest errors in data.

3 The Case Study

We have applied our method to an example problem. We wanted to know how our method works and what kinds of problems we would face in such a case study. We first briefly describe the case and then go into discussing our experiences.

3.1 The example problem

A small Napier-based quilting company in New Zealand has asked a small software vendor to set up an e-Commerce site, as they lack any IT-knowledge. Quilting is a needlework process in which layers of material are attached to each other with continuous stitches, either by hand or with specialist machines to make a quilt. This quilting company sells quilting machines, patterns as well as finished products.

The software vendor has used the Rational Unified Process in the development of previous ECIS, has some experience in storyboarding and user profiling and some of their previous ECIS have been developed using Agile methods. They have been in business for three years, have two full-time staff and use part-time staff when required. Data was gathered from the software vendor developers by interviewing them concerning the relevant quality aspects.

3.2 e-Process ranking

The e-P quality aspects given above were used and the admissible e-Ps were:

- Rational Unified Process (RUP);
- Open source development process – the "bazaar" approach (Raymond, Cathedral and Bazaar, 2001) (OSS);
- Agile and extreme programming ECIS development process (AX);
- Development process using storyboarding and user profiling (SBUP).

Each e-P in this list is all well-known and documented software processes and provides a variety of options to the developer. No explicit expert selection was carried out as it was determined that the members of our developing team had enough e-P knowledge to be able to come up with a set of the expert values. To incorporate the expert values, quality aspects hierarchy, and other data necessary for selection, the BPMM Selector tool (Kaschek, Pavlov, et. al., 2006) was adapted (we called the adapted version of the tool *e-Process selector*). All the calculations were performed using this tool.

Quality Aspect	*e-Process assessment*							
	RUP		*OSS*		*AX*		*SBUP*	
Completeness	1	0,60	5	0,12	3	0,20	7	0,09
Understandability	1	0,17	1/3	0,50	1	0,17	1	0,17
Visibility	1	0,58	5	0,12	3	0,19	5	0,12
...								

Table 1: Selected experts' e-P quality aspect scores

The alternatives are evaluated by the experts against each second-level quality aspect to determine the results. Table 1 shows a subset of the assessments (expert-supplied comparison values a(c,1,x,y) and the normalized assessments $f_{c,x}$).

3.3 System quality aspect ranking

In the interview, the ECIS developers scored the importance of the quality aspects to the problem. Tables 2 and 3 show a part of the developer comparison values and the normalized assessments for the top level- and second level quality respectively.

e-P aspects		*Quality concepts*		*Cost*		*Domain impact*	
1	0,048	1/3	0,143	1/5	0,238	1/3	0,143
Usability		*Compatibility*		*Maturity*			
1/5	0,238	1	0,048	1/3	0,143		

Table 2: Top level quality aspects scores

e-P aspects	*Completeness*		*Understandability*		*Visibility*		*Supportability*		*Maintainability*	
	1	0,08	3	0,03	1	0,08	1/7	0,57	1/3	0,24
Quality Concepts	*Readability*		*Reliability*		*Robustness*					
	1	0,09	1/5	0,46	1/5	0,46				
...										

Table 3: Selected second-level quality aspects scores

3.4 Knowledge blending

The final e-Process scores are shown in **Table 4**. As the Rational Unified Process is the e-Process with highest score it is the recommended alternative for the project.

RUP	*OSS*	*AX*	*SBUP*
0,349	0,235	0,294	0,122

Table 4: Final e-Process scores

The example was purely illustrative and we will not explore the result further. It is, however, interesting that with a complicated process such as the AHP, which hardly permit prediction of the outcome, we could reproduce the developers' predisposition.

3.5 Tradeoff Analysis

For our case study we illustrate the tradeoff analysis regarding "Visibility" and "Robustness" with the tradeoff diagram depicted in Figure 3. The diagram shows that SBUP and AX both score relatively low with respect to both quality aspects and that RUP favors "Visibility" over "Robustness" while OSS does the opposite.

We used MS Excel for creating the tradeoff diagrams (more than 400). Over 90% of these showed tradeoffs. Among them, 124 diagrams showed tradeoff for one e-P, 192 – for two e-Ps, and 54 - for three e-Ps. Two diagrams ("Team Experience" vs. "Running Costs" and "Documentation" vs. "Running Costs") showed tradeoffs for all the e-Process alternatives. That indicates that none of the admissible e-Ps is optimally suited regarding the three quality aspects "Documentation", "Running Cost", and "Team Experience".

3.6 Sensitivity analysis

We created the sensitivity diagrams for the case study with HIPRE v. 1.22 available at http://www.hipre.hut.fi. Rank reversals occurred expectedly mainly for top-level quality aspects, i.e., “Quality Concepts”, “Cost”, and “Usability”. We found, however, that rank reversals occurred also for the second-level quality aspects “Geographic Interaction” and “E-Process Knowledge”. The first-level percent-top critical quality aspect was “Cost”.

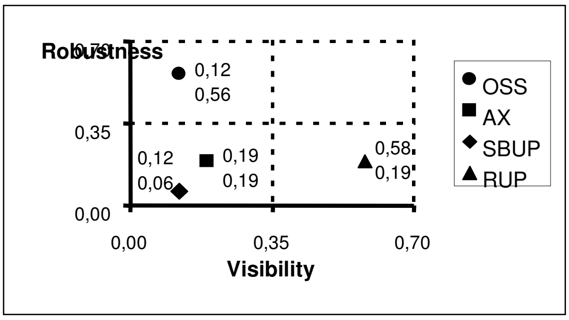

Figure 3: Tradeoff diagram regarding “Visibility” vs. “Robustness”

Figure 4 contains a sensitivity diagram showing rank reversal that occurred in our case study. The diagram shows that changing the “Quality Concepts”-score from the current value (about 0.143) to approximately 0.4 implies a rank reversal (i.e. AX will go on top of RUP). Knowledge about rank reversals may be important because for small changes in the quality aspect score they indicate caution to be advisable regarding the e-P assessment and reconsideration being an option. Our finding is remarkable because shows that “Quality Concepts” is not a top-scored high-level quality aspect.

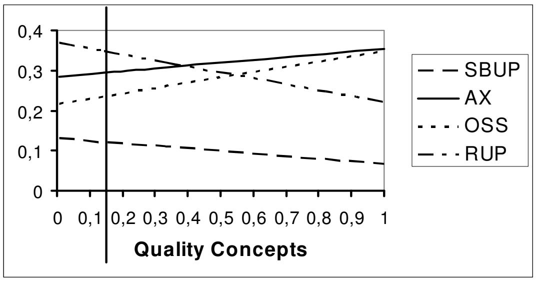

Figure 4: Sensitivity diagram - “Quality Concepts”

An analysis of our results is available on request.

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