The GRADE Decision Canvas for Classification and Reflection on Architecture Decisions

Efi Papatheocharous[1], Kai Petersen[2], Jakob Axelsson[1], Claes Wohlin[2], Jan Carlson[3], Federico Ciccozzi[3], Séverine Sentilles[3], Antonio Cicchetti[3]
[1]*Swedish Institute of Computer Science, Kista, Stockholm, Sweden*
[2]*Blekinge Institute of Technology, Karlskrona, Sweden*
[3]*Mälardalen University, Västerås, Sweden*
firstname.lastname@sics.se[1], *bth.se*[2], *mdh.se*[3]

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Abstract: This paper introduces a decision canvas for capturing architecture decisions in software and systems engineering. The canvas leverages a dedicated taxonomy, denoted GRADE, meant for establishing the basics of the vocabulary for assessing and choosing architectural assets in the development of software-intensive systems. The canvas serves as a template for practitioners to discuss and document architecture decisions, i.e., capture, understand and communicate decisions among decision-makers and to others. It also serves as a way to reflect on past decision-making activities devoted to both tentative and concluding decisions in the development of software-intensive systems. The canvas has been assessed by means of preliminary internal and external evaluations with four scenarios. The results are promising as the canvas fulfills its intended objectives while satisfying most of the needs of the subjects participating in the evaluation.

1 INTRODUCTION

The growing complexity and size of modern software-intensive systems have put architectural design decisions at the forefront of the concerns of software and system engineers. Many intricate factors need to be considered in decision-making, such as continuous deliveries and qualitative large-scale complex systems to be developed with flexible architectures for future adaptations and maintenance. An important factor which allows the efficient adaptation and evolution of architectures is enabling access to information and resources to make appropriate decisions in a timely manner.

Towards achieving this, a decision canvas template has been developed within the ORION research project (http://orion-research.se/). The canvas can be used for carrying out meaningful discussion among decision-makers and gives support in the process of decision-making by introducing the most important elements to document and describe a decision. The canvas is also making use of a dedicated decision taxonomy (denoted GRADE taxonomy and introduced in (Papatheocharous et al., 2015)).

In particular, the proposed decision canvas allows software and system engineers to express decision scenarios in a unique illustrative and structured manner, by using a template, which takes into account relevant properties and contextual elements regarding a decision. These characteristics comprise of for example relevant decision requirements, benefits, constraints and contextual information which once defined, are useful to position decisions in relation to other decisions made in the complex software-intensive systems landscape. Once the related elements to a decision are captured, they can be easily accessed to classify decisions and serve as facilitators for decision discussions.

This paper presents the GRADE decision canvas template, a development motivated by the observation that architectural decision-making is often conceived as a complex problem with no tangible formulation (Van Vliet and Tang, 2016). Decision problems and their solutions are difficult to describe, access and reuse. Making better decisions heavily depends on the ability to capture, understand and communicate the information involving the decisions to the decision-makers and other respective stakeholder roles. Yet many decisions lack this support, causing inability to reflect on past decision-making activities for future circumstances of architectural knowledge/decision reuse. Given the importance of this topic and its consequences on the selection of technological solutions for the development of software-intensive systems (e.g., software services, components, platforms and systems), the lack of support for capturing, understanding and communicating information and the rationale behind decisions is surprising, even though the complexity and fuzziness of the topic of architecture decisions for modern software-intensive systems makes it understandable.

The GRADE decision canvas pursues two objectives: (1) to serve as a common vocabulary and basis for practitioners to capture, discuss, understand and communicate decisions, and (2) to serve as a way to reflect on past decision-making activities for tentative and concluding decisions in the development of software-intensive systems. In this respect, this work presents the decision canvas in detail and also exemplifies its usage through a set of preliminary evaluation activities. It discusses how the template can be used to document decision scenarios by means of concrete cases, used as evaluation opportunities, and also provide a basis for carrying out discussions among decision-makers.

The remainder of the paper is organized as follows: Section 2 discusses existing work related to this contribution, while Section 3 presents the GRADE decision canvas. Section 4 describes the evaluation conducted for the canvas. Section 5 concludes the paper and presents future investigation directions.

2 RELATED WORK

A lot of the information involved in architecture decision-making is sensitive and relatively hard to access. Decision knowledge regarding current or past cases of architectural design is of primal importance to improve decision-making, or at least to avoid falling into the same pitfalls as in the past. Such knowledge about architectural decisions gets often lost among practitioners' meeting minutes, oral conversations, white boards, reports and note books, and is not easily accessible to others (researchers, academics or practitioners).

Several efforts have been focused on the definition of structures to support capturing of architectural knowledge. For example, in (Tyree and Akerman, 2005) decision templates are presented in the form of tables to capture the design rationale and context. In (Van Heesch et al., 2012a) decision views based on the conventions of ISO/IEC/IEEE 42010 are described to support documentation. In (Van Heesch et al., 2012b) the system context of decisions is defined by a set of forces affecting the problem, i.e., any aspect of the problem considered when solving it. In (Manteuffel et al., 2016) the implementation of a tool for documenting decisions is presented. The authors show that it increases quality of decision documentation and productivity, while it is considered highly useful to software architects. In the above works the issues of usefulness, perceived ease of use and documentation effort are raised as primary concerns. As such, they lack appropriate visualization support and a common vocabulary as basis. This lack causes inability to communicate and understand decisions as well as to reflect and discuss on past decision-making over time.

Understanding and documenting decisions within the area of architectural design of software-intensive systems is a great challenge. This is due to the fact that the fundamental concepts related and affecting the decision process are inherently complex and difficult to capture, document and maintain. Some of these concepts include for example information about what the decision is about, who is participating in the decision, what the considered alternatives are, and the decision rationale. These concepts and specifically: *Goals*, *Roles*, *Assets*, *Decision*, and *Environment* are the fundamental concepts included in a decision support taxonomy, denoted GRADE, coined previously in (Papatheocharous et al., 2015). The GRADE decision canvas proposed in this paper, makes use of this taxonomy to support architecture knowledge capture.

In (Tang et al., 2008) the authors showed that architecture design quality improves when designers are equipped with knowledge on design reasoning. A repository to serve knowledge extraction and evidence-based support for future decision support is therefore needed. In order to construct the knowledge repository, continuous, reliable, transparent and practical data collection needs to be established. The GRADE decision canvas, presented in the next section, aims to support exactly this purpose.

3 GRADE DECISION CANVAS

The GRADE decision canvas has been created using design science (Peffers et al., 2007), in which concrete artefacts are created and evaluated in an iterative way. Specifically, we conducted two evaluation rounds one internal and one external. The GRADE decision canvas, shown in Figure 1 is used to provide a useful architectural data collection and communication mechanism, as well as to carry out discussions around the decision.

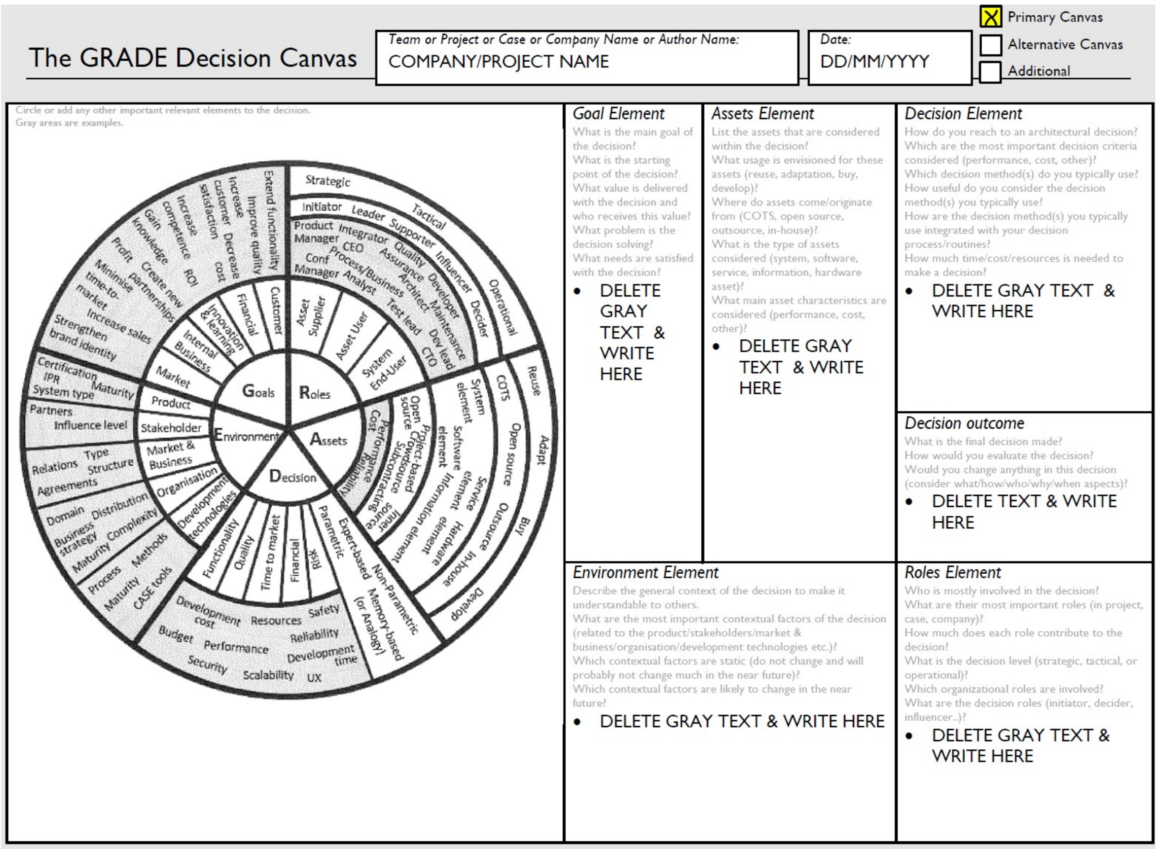


Figure 1: GRADE decision canvas template.

On the top of the template, meta-information about the decision is specified: team or project or case or company name involved in the decision, date and whether the canvas is the primary one, an alternative canvas or additional to other canvases.

In the main part of the canvas the left-hand side depicts the GRADE taxonomy overview diagram, which illustrates the high level categories used to describe decisions, along with lists of examples (shown in gray). These categories are defined in detail in (Papatheocharous et al., 2015), and consist of the following:

- *Goals (G):* describes the main goal of the decision as a value which contributes to one or more perspectives, such as customer-perspective, financial-perspective, innovation & learning perspectives, internal business-perspective, and market-perspective.
- *Roles (R):* describes the stakeholders of a decision. They are described based on literature studies in decision-making, i.e., (Tan and Sheps, 1998), (Herrmann et al., 2004) and (Morisset et al., 2014).
- *Assets (A):* describes the different alternatives or options of considered assets.
- *Decision (D)* methods and criteria: describes the way to reach to a decision and the criteria (or properties) used.
- *Environment (E):* describes the context of the decision one needs to know to understand the decision case.

Each of these categories is illustrated as a slice in the GRADE taxonomy overview diagram (left-hand side of Figure 1). They can be used as a checklist to capture the important elements in architectural decision-making in software and systems engineering.

On the right-hand side of the canvas, the following questions are listed for each GRADE decision canvas category to capture their most important aspects:

- *Goal (G) Element:* What is the main goal of the decision? What is the starting point of the decision? What value is delivered with the decision and who receives this value? What problem is the decision solving? What needs are satisfied with the decision?
- *Roles (R) Element:* Who is mostly involved in the decision? What are their most important roles

(in project, case, or company)? How much does each role contribute to the decision? What is the decision level (strategic, tactical, or operational)? Which organizational roles are involved? What are the decision roles (initiator, decider, or influencer)?

- *Assets (A) Element:* List the assets that are considered within the decision? What usage is envisioned for these assets (reuse, adaptation, buy, or develop)? Where do assets come/originate from (COTS, open source, outsource, or in-house)? What is the type of assets considered (system, software, service, information, or hardware asset)? What main asset characteristics are considered (performance, cost, or other)?
- *Decision (D) Element:* How do you reach to an architectural decision? Which are the most important decision criteria considered (performance, cost, or other)? Which decision method(s) do you typically use? How useful do you consider the decision method(s) you typically use? How are the decision method(s) you typically use integrated with your decision process/routines? How much time/cost/resources is needed to make a decision?
- *Environment (E) Element:* Describe the general context of the decision to make it understandable to others. What are the most important contextual factors of the decision (related to the product/stakeholders/market & business/organisation/development technologies etc.)? Which contextual factors are static (do not change and will probably not change much in the near future)? Which contextual factors are likely to change in the near future?
- *Decision outcome:* What is the final decision made? How would you evaluate the decision? Would you change anything in this decision (consider what/how/who/why/when aspects)? Decision outcome is a required addition to the elements described in the GRADE taxonomy, to be able to track outcomes of the decision process to be used in future decisions.

The questions may be used as guidelines to collect issues of primary interest in decision cases. These questions are based on points of interest identified in previous work investigating architectural decisions (Petersen et al., 2017). The decision canvas is provided in an electronic editable form (available here: http://orion-research.se/GRADE/canvas16.pdf), i.e., the gray text is to be replaced by practitioner's responses.

The GRADE decision canvas has been evaluated by means of two preliminary evaluation rounds, described in detail in the next section.

4 PRELIMINARY EVALUATION

We present the evaluation method (Section 4.1), and the results of the evaluation (Section 4.2). First, an internal evaluation round was carried out (within the development team of the canvas) and based on the feedback we created a new version of the canvas (as presented in Section 3). Then, we conducted an external evaluation round (outside the development team, but still within the project). The purpose of the evaluation is to stand as static preliminary evaluation with a limited scope. The plan is to further revise the canvas based on more types of evaluations, including piloting in industry, to ensure a mature and useful decision canvas for architectural decisions in industry.

4.1 Method

The evaluation method includes defining the following:

Definition of research questions: The following research questions were considered to assess the objectives of the GRADE decision canvas (see Section 1): *RQ1: Would two individuals, who are independently classifying the same decision scenario, reach similar classifications? RQ2: Would individuals using the canvas to convey the details of a decision scenario, find the canvas useful for reflecting on decision-making activities?*

Selection of subjects: The evaluation was done internally (utilizing researchers who were also creators of the GRADE taxonomy (Papatheocharous et al., 2015)) and externally (utilizing researchers who were not involved in neither the GRADE canvas nor taxonomy creation). For the internal evaluation we utilized some of the co-creators of the GRADE taxonomy, to identify shortcomings with respect to the usage of the taxonomy as a common language. They made use of two decision scenario descriptions produced in the context of the ORION project and improvements to the canvas were carried out based on the results of this internal evaluation. The motivation for utilizing the creators was that they were already familiar with the GRADE taxonomy and its terminology and thus did not require any training. Nevertheless, the risk is that no other outsider perspective would be considered, which limits the external validity of the findings. Thus, in the internal evaluation one researcher and in the external evaluation two researchers who have not been involved in the GRADE taxonomy creation were involved to overcome the limitations.

Data collection: For the internal evaluation we chose to utilise two decision scenarios to increase the generalizability of the findings. The scenarios were

Table 1: Data Collection

Scenario	Scenario description	Creator	Evaluators
MOPED	A decision problem of allocating an image processing system to different ECUs	J. Axelsson	Internal (K. Petersen and S. Sentilles)
Global	A decision problem of outsourcing versus in-house development	K. Petersen	Internal (A. Cicchetti and F. Ciccozzi)
LiICSE	Decisions to choose among COTS and OSS components	(Li et al., 2006b)	External (C. Wohlin and J. Carlson)
LiEMSE	Decisions to choose among build or buy options	(Li et al., 2006a)	External (C. Wohlin and J. Carlson)

described independently by two persons and were within the domains of automotive (MOPED) and automation (Global). The scenario descriptions were 9 and 4 pages long (contained about 2650 and 1400 words) respectively. The descriptions were reviewed independently by two persons whom were not involved in the scenarios' creation. Using the GRADE taxonomy overview in the decision canvas (see left-hand side of Figure 1), they classified the scenarios independently. This was carried out to validate the consistency of using the GRADE decision canvas. The right-hand section of the decision canvas was also used as means for data collection. Table 1, first two rows, provides an overview, the evaluators and the authors of the two scenarios (MOPED and Global). Each evaluator marked on the canvas (either electronically or using pen and paper) the parts in the canvas they identified as relevant to the scenarios. When they found information that was not present in the GRADE taxonomy they added the information as additional notes (using the provided questions as guidelines).

The information was extracted in a spreadsheet and thereafter used to determine the consistency with which the evaluators classified the scenarios. Subsequently, the creators and evaluators commented independently on the actual usage of the decision canvas for illustrating the scenario and its usability for reflecting the decision for future activities. This feedback was used to improve the canvas. If, from the two evaluators, similar elements are identified then this was an indication that different persons interpreted the scenario in the same way.

The external evaluation was performed in a similar manner by two evaluators carrying out the following steps:

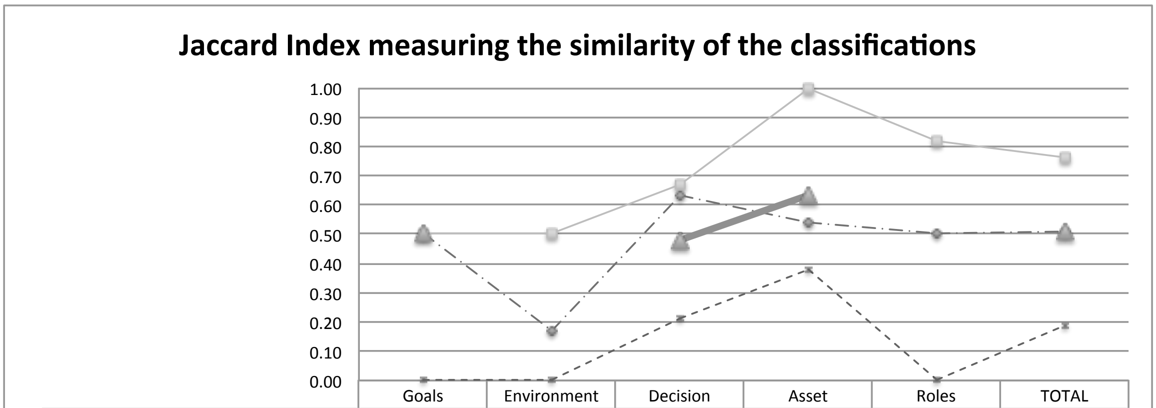
- Select papers for scenario extraction. The first author of a systematic literature review on architectural decision-making (Badampudi et al., 2016) was asked to select two papers from the papers included in the review that she judged as being reasonable to describe using the GRADE canvas. Not all papers included in the literature review covered actual decisions or studies of decisions; some papers presented methods for making a selection of a software asset, and these papers are not suitable for classification using the GRADE canvas. Based on this, random selection was discarded as a suitable method, and hence the first author made an informed recommendation of articles to use in the external evaluation. The two papers selected are presented in the last two rows of Table 1.
- Independently extract and classify the information provided in the selected papers using the same procedure as for the internal evaluation.
- The two evaluators discussed their findings and observations with each other and with one of the other authors observing and taking notes.
- The two evaluators provided individual summaries of their findings and observations for analysis and comparison.

Data analysis: To answer the first research question (*RQ1*) we compared the classification of the scenarios to determine the similarity. Each element identified by the first evaluator is counted as part of set A and each element identified by the second evaluator is counted as part of set B. We then utilized the Jaccard index (McCormick et al., 1992) for the comparison, which is defined as:

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|}. \tag{1}$$

The index provides a value of $0 \leq J(A,B) \leq 1$, the closer the index is to 1 the higher the similarity. To answer the second research question (*RQ2*), analysis and synthesis of the feedback received was carried out and a summary is provided in the results section.

Validity threats: Two main threats have been identified with respect to the internal and external evaluations. First, the evaluators are members of the project where the GRADE canvas has been developed, and they may have acquired some knowledge about the canvas, even without participating in its development. Second, K. Petersen (creator of one of the scenarios) and D. Badampudi (selector of the papers from the literature review) have both taken part in the development of the GRADE taxonomy, and thus there is a risk that they may have affected the formulation of the evaluation of the GRADE canvas, i.e., may have caused to favour aspects from the decisions in the sce-



	Goals	Environment	Decision	Asset	Roles	TOTAL
Internal:MOPED:(Kai;Severine)	0.50	0.17	0.63	0.54	0.50	0.51
Internal:Global:(Antonio;Federico)	0.50	0.50	0.67	1.00	0.82	0.76
External:LiICSE2006:(Claes;Jan)	0.50		0.48	0.63		0.51
External:LiEMSE2006:(Claes;Jan)	0.00	0.00	0.21	0.38	0.00	0.19

Figure 2: Jaccard Index for the evaluated scenarios and papers

narios over others. Despite the threats, it was identified that several aspects are not sufficiently covered by the canvas, and hence areas for improvement were identified.

4.2 Results

The results are structured according the research questions formulated in Section 4.1.

4.2.1 RQ1: Similarity of classifications

First, we present the quantitative findings and then the qualitative feedback/reflections provided by the evaluators to explain the reasons for the differences and the avenues for improvements to the canvas.

Quantitative findings: Figure 2 shows the Jaccard index values for the decisions in the two evaluations. When the Jaccard index is high then two evaluators reading the same scenario have a more similar view about the classification of the scenario. Overall, the Jaccard index shows rather low values for the consistency among evaluators, both internally and externally. From the figure it is also visible that the similarity was highest for the Global scenario. The main difference of the Global and the rest was that the Global scenario's description was much more structured, i.e., the decision-making steps were grouped and the information was easier to identify.

Furthermore, it is interesting to observe that the *Goals* and *Environment* dimensions have the lowest similarity values among the main elements. This is due to some difference identified when it comes to the level of detail marked down by the evaluators.

Qualitative reflections: We first explore the reasons for the differences. The internal evaluators identified that some of the canvas elements' levels were not clear. For example, they had difficulty to find all the categories of Roles applicable. The ordering of the categories was also found confusing, i.e., Asset origins, types, and properties. It was also unclear if the term "system" includes both software and hardware. Some questions appearing in the right-hand side of the canvas were also found unclear. Also, defining the connection between different decision cases over time was not easy to do. The evaluators also mentioned that the items' placement in the right-hand side of the canvas and the elements on the left-hand side was not perhaps the optimal one.

Other remarks for improvement included: some duplicate items appear within the Assets and Decision criteria (e.g., Cost), and as these are examples, the canvas could have been better without examples (i.e., the canvas could have the leaves of the taxonomy empty and based on the decision case to be filled-in). A final remark from the internal evaluation was to consider renaming Assets to Alternatives.

The external evaluators highlighted that both papers they used discuss decision-making in general rather than presenting a specific decision case. Based on this, it was impossible to make a classification of the Environments and the Roles involved. It was impossible for two reasons, first the demographics are not described on that level of detail, and second even if it would have been described the mapping to specific decisions is not described. Inconsistencies occurred also due to one reviewer highlighting that it was not possible to use Environment and Roles, while the other used the GRADE taxonomy to describe the demographics of the study. Hence, a well-defined unit of analysis (decision) may be used to increase the consistency. Some indication of this is provided by the high values achieved for the internal Global scenario, which was a structured and focused decision case.

Further issues raised were: priorities are not supported in the canvas (e.g., with respect to what are the most important decision criteria). It was unclear why the last level of Roles (i.e., strategic, tactical, and operational) appears in that category. It was typically not explicitly stated in the papers if a certain role was representing the strategic, tactical or operational level. Hence, this information may be better suited to characterize goals or decisions. The order by which roles are presented was suggested to be changed, having the items on the second and third level first.

The structure of the GRADE taxonomy overview diagram was also a source for inconsistencies. In particular, items or words were found in more than one place. It was perceived unnecessary, since the objective is to support decision-making and not necessarily ensuring completeness with respect to all aspects. Two examples of redundant information is the presence of "Open Source" in two levels within Assets, and the use of "Cost" in different shapes. Cost appears in the Goals category, but also in the Assets category. Though, the goals will drive the aspects to be considered in both the decisions and the expectations of the assets. For example, if the goal is to decrease cost then cost must be a key aspect in the decision and strongly related to the actual asset. Given the redundancy of items, both reviewers may want to indicate the same, but in the statistical analysis a disagreement is shown as they provide their information in different places of the taxonomy. Thus, in practice the agreement may in fact be higher than indicated by the Jaccard index.

4.2.2 RQ2: Implications and usefulness

The internal as well as external evaluators highlighted the utility of the GRADE decision canvas. We first present the remarks of the internal evaluators:

- *Ease of use:* The main feedback from the evaluators of the canvas was that they found it to be simple to use, intuitive and practical. The usage of the canvas was done without requiring almost any guidance. Some clarifications might be needed though for individuals not familiar with the GRADE taxonomy. In the future it is suggested that the elements defined in the GRADE taxonomy should be provided to practitioners together with the canvas.
- *Accessibility after classification:* Decision cases and their details captured with the canvas are easier to read. Reading the decision cases details in the template format was more intuitive and faster to process than in a textual descriptive form.
- *Ability to completely capture a scenario:* The authors of the decision scenarios found that their scenarios were well captured with the canvas by both individuals to a sufficient level of detail and that nothing crucial was missing (complete when doing in pairs). This is why the canvas is suggested to be used for consensus discussions based on individual usage of the canvas.

The following reflections and usages for the GRADE decision canvas were presented by the external evaluators:

- *Ambition of GRADE with regard to completeness:* The GRADE taxonomy cannot ever be complete. The latter would require including all quality aspects covered by all different quality models and standards. This is infeasible, and hence incompleteness has to be accepted.
- *Usefulness for describing decisions:* Despite the relative low formal agreement, the canvas (in particular if improved) is helpful as a tool to describe a decision. It makes a number of items (words) explicit and as such a good basis for discussions. Overall, the impression was that it is a useful tool to capture important aspects of a decision case.
- *Facilitator for a discussion around decisions:* The canvas supports the discussion around a decision, but it is insufficient to describe a decision without a consensus discussion. In other words, the canvas is primarily a facilitator for discussions around a decision. This is further supported by the inconsistencies when individual reviewers conduct an assessment, though the combined results and discussions allow convergence.
- *Towards achieving reliability:* To accurately document and classify decision scenarios the external evaluators suggested that practitioners should first use the canvas to capture their own view. Then, carry out discussion in pairs to achieve more reliability. They highlighted that through a discussion on the disagreements they would be able to suggest a joint classification that they both agree on.

5 CONCLUSIONS

In this paper we proposed and carried out a set of preliminary semi-formal evaluation rounds of the GRADE decision canvas for decision-making support in architecting software-intensive systems. We found that, despite the relatively low levels of formal agreement between the evaluators, the GRADE decision canvas is a helpful tool to describe decisions. It makes the characteristics of a decision explicit and thus provides a sound basis for discussions. The GRADE decision canvas supports the discussion around a decision, but it is insufficient to describe a decision without a consensus discussions. In other words, the GRADE canvas is primarily a facilitator for discussions around a decision. Thus, the GRADE decision canvas can be used to illustrate in a comprehensive and structured way decision scenarios even from different individuals. It can serve as a common vocabulary and basis to capture, understand and communicate decisions, as well as reflect on decision-making.

One important limitation of the canvas is the difficulty to effectively visualize the relations between the elements describing a decision and even the relations between different decisions. This makes it difficult to carry out trade-off and impact analysis of the options within a decision. We are currently investigating possible ways to overcome this issue and thereby making those analyses possible for the GRADE canvas.

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