Value-Based Decision-Making Using a Web-Based Tool: A Multiple Case Study

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***Abstract*—[Context]: To remain competitive, innovative and to grow, companies should use a value-based decision-making where decisions are the best for that company's overall value creation. However, without tool support, the use of explicit value propositions and aggregation of different key stakeholders' decisions during decision-making may be a challenge for many companies. [Goal]: The goal of this paper is to investigate the extent to which a Web-based tool for value-based decision-making can successfully support stakeholders' decision-making process. [Method]: We conducted three case studies across four software projects, during six weeks, in the contexts of feature selection, test cases execution prioritization and user interfaces design selection. Prior to using the tool, stakeholders' value propositions were elicited via focus-group meetings; later, during a post-mortem phase, data was gathered via observation, semi-structured interviews and structured questionnaires. [Results]: Participants reported an improvement of their decision-making process and quality of decisions; further, they also felt confident about using the tool, and that it can be useful to their work. [Conclusions]: Results suggested that the use of tool support by the stakeholders in the investigated company for value-based decision-making improved their decision-making process and the quality of decisions.**

***Index Terms*—Value-based decision-making; Value-based software engineering; tool support**

I. Introduction

A. Motivation

To remain competitive and to sustain growth, software companies must tackle the accelerated rate of changes in technology, pursuing new strategies to gain competitive leverage and differentiate themselves from their competitors [1]. Such competitive leverage can be achieved by incorporating both short- and long-term value aspects in order to guide their decision-making [2] [3] [4]. To incorporate a value-based approach to the decision-making process, it is important to first identify who the success critical stakeholders are and what are their value propositions, prior to using such knowledge in the decision-making process [4]. Further, once key stakeholders' value propositions are made explicit, it becomes important that companies are able to use such explicit representation during decision-making. A value-based decision-making scenario involves several items to decide upon, several key stakeholders making decisions about those items, and decision criteria represented by the stakeholders' explicit value propositions. Given the complexity of such scenario, we have proposed and employed, as part of an ongoing research project in collaboration with several industrial partners in Finland, a Web-based tool (VALUE tool) to support value-based decision-making processes within the context of software/software-intensive products [3] [5] [4].

B. Research Goals and Contribution

This paper has two main goals, as follows: i) to assess whether the VALUE tool helped the company case improve their decision-making process; and ii) to measure the VALUE tool's acceptance level based on its use in a number of decision-making scenarios in the company case. This latter goal, i.e., the behavioral intention and use behavior, can give us useful insights on the likelihood of success of the VALUE tool, and whether further tool improvements and even training are needed [6].

With regard to this paper's contribution, it is twofold: (i) from a research point of view, the Value-Based Software Engineering (VBSE) community can learn from the results related to the two abovementioned research goals, which relate to using the VALUE tool to support value-based decision-making within the context of software/software-intensive products; (ii) from a practitioner's perspective, this paper provides useful insights on the benefits of using the VALUE tool to support a value-based decision-making process.

C. Research Context

The study was carried out at the Embedded Laboratory – a software development laboratory located at the Federal University of Campina Grande, Brazil. It has approximately 60 employees and the development teams are composed by junior developers working part-time and full-time project managers with previous industry experience. The projects are executed in partnership with other companies (their customers) to develop software products or prototypes. The developers follow mature software development processes and the projects are executed following a Scrum-based process in which teams have between three and seven developers. There is also a Software Quality Assessment (SQA) and a User Experience (UX) team. The SQA team is responsible for assessing the quality of the development teams' deliverables and to execute sanity and exploratory tests. The UX team is responsible for defining the products' user interfaces. The company produces Web and mobile-based software in several contexts such as embedded, pervasive computing and finance.

The remaining of this paper is structured as follows: In Section II we present the related work and earlier studies. Section III describes the proposed Web-based solution investigated herein and Section IV presents the research method, further, Section V details the results from each case study, followed by Section VI where research questions are answered and results are discussed. Section VII presents threats to validity and finally, in Section VIII we give our conclusions and comments on future work.

II. Background and Related Work

A. Earlier Studies

Software-intensive industry work their way through the software development process making several decisions in different layers, from technical decisions to managerial and strategic decisions. Thus software engineering can be considered as decision-making [7]. Considering the importance of decision-making in software engineering, some studies suggests it is not widely explored by the research community [7] [8].

Moreover, classical decision models address decision problems with algorithm for making optimal decisions [9] [7], in many cases only considering trade-off analysis and cost-based aspects [2]. While such strategy can work in highly constrained cases, it brings challenge when dealing with complex decision domains.

VBSE emerged in 2003, stressing the importance of thinking value in software-related decisions by balancing short and long-term goals [2]. It introduced a wider view of value that exceeds its economic focus by including aspects such as "relative worth, utility, or importance", and also presented the concept of key stakeholder to refer to all stakeholders who need to participate in the system definition and development processes.

In relation to software tool support for VBSE, a recent systematic literature review [10] identified 10 tools. The majority of these tools support requirements engineering activities (9), such as requirements prioritization and elicitation. The remaining tools relate to planning and control (1), verification and validation (1), and risk management (2). Note that some tools focused on more than one VBSE area.

Value-based decision-making tools have been proposed by McZara et al. [11], Bebensee et al. [12], Saliu and Ruhe [13], Achimugu et al. [14] and Kukreja et al. [15]. However, the tools reported in [15] and [12] are prototypes implemented using spreadsheet, which makes collaboration between the key stakeholders challenging. The tool presented in [13] is a commercial solution focused on project management and release planning, limiting the decision-making scenarios. The remaining tools [11] [14] did not provide a way to represent the stakeholders value considerations.

In summary, none of the abovementioned tools provided in their implementation mechanisms to enable the representation of key stakeholders' value propositions and collaborative functionality and individual as well as group decision-making mechanisms. Such gap has motivated the development of the VALUE tool, which is part of a wider research solution – the VALUE Framework, briefly introduced next, and detailed elsewhere [3].

B. The VALUE Framework

The VALUE framework is part of a larger research project, in collaboration with four industrial partners in Finland [3], which aims to improve value-based decision making and to forecast the value of decisions in the context of software/software-intensive products. This Framework employs a mixed-method approach to support software companies in improving their value-based decision-making. Its five distinct parts are as follows: (i) elicitation of company-specific value factors; (ii) use of the identified value factors with tool support in decision-making processes; (iii) semi-automatic generation of probabilistic value estimation models; (iv) validation of value estimation models; (v) add-on value estimation models for use in decision-making processes [3]. Only parts (i) and (ii) are relevant herein.

As will be detailed later, the case studies presented in this paper use the same method as per the VALUE framework (e.g. focus group meetings with key stakeholders to jointly elicit value propositions to be later used in the VALUE tool).

C. Unified Theory of Acceptance and Use of Technology

To understand the end-user acceptance level of the VALUE tool, we used the Unified Theory of Acceptance and Use of Technology (UTAUT). The success of a software solution can be evidenced via its subsequent and continued use by end-users. In order for such subsequent and continued use to occur, such solution must be perceived to be useful and easy to use [16]. In an attempt to propose a unified view to understanding technology usage, Venkatesh et al. proposed a unified model called UTAUT [6]. The UTAUT model was formulated using four core determinants of intention and usage: performance expectancy, effort expectancy, social influence, and facilitating conditions [6]. Within the context of the three case studies detailed herein, we have also assessed the likelihood of success of the VALUE tool using a questionnaire based on the UTAUT model.

III. The VALUE Tool

The VALUE tool is a Web-based tool that enables the representation of key stakeholders' value propositions, supports a well-organized decision process and allows for past decisions to be documented systematically. Given the tool can be used in many different decision-making scenarios, we adopted the terms "deliverable" as a generic name that can represent a product, a project, a release or a service, and "decision item" as a generic name to identify a feature, a requirement, a use case, a bug, an idea or anything a decision is targeted at.

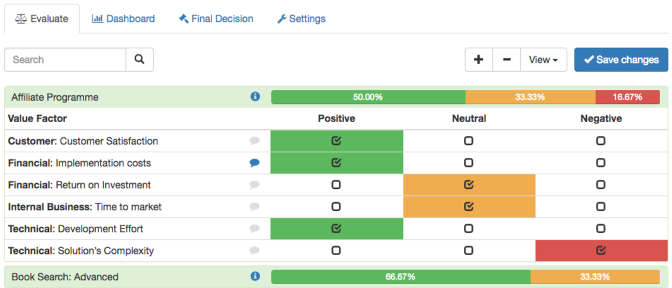

Fig. 1. Individual assessment using the VALUE tool.

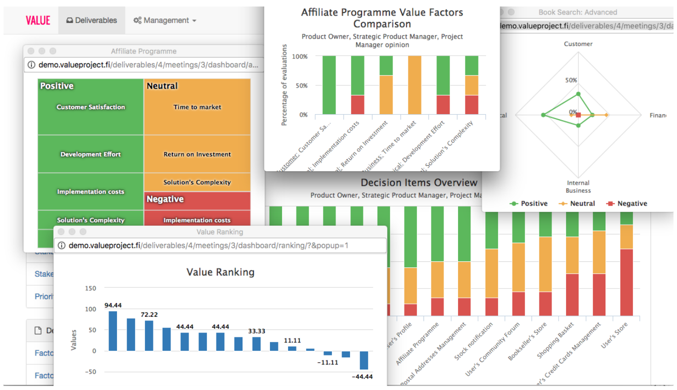

Fig. 2. Data visualization using the dashboard.

Prior to using the VALUE tool, a Company needs to choose the decision scenario(s) where it will be employed, and also the key stakeholders who will participate in the decision-making process(es) relating to the chosen scenario(s). The next step, which corresponds to part (i) in the VALUE Framework, is to identify what value means to those key stakeholders, so making explicit their tacit knowledge in regard to their value propositions (value factors henceforth). Examples of value factors are: Customer Satisfaction, Return on Investment and Time-to-Market. Note that the set of value factors are company-specific. Once value factors are identified, stakeholders must agree on how to measure the likely effect/impact that the selection of a given decision item will have upon each of the value factors. For example, Fig. 1 shows that Stakeholder "Vitor Freitas" believes that the implementation of the feature called "Affiliate Programme" into the existing product (Second Hand Books website) will likely have a positive impact upon the value factor "Customer Satisfaction", and a negative impact upon the value factor "Solution's Complexity". In this scenario, impact is being measured as "positive", "neutral" and "negative"; however, this is also a company-specific decision (even the use of the term impact or an alternative term).

The VALUE tool, which corresponds to part (ii) in the VALUE Framework, encompasses a decision-making process using three distinct functionalities: (i) individual assessment; (ii) group assessment; and (iii) final decision. Note that the tool's design was co-created with the four industrial partners in the research project where the VALUE tool is being developed.

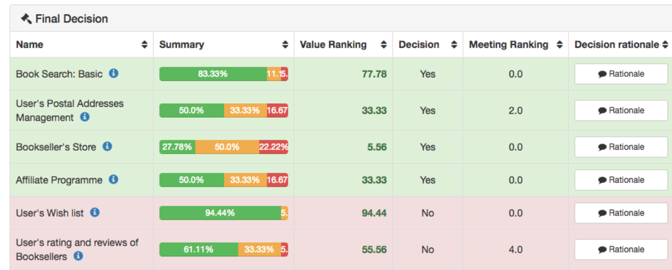

Fig. 3. Final decision recorded in the VALUE tool.

The individual assessment enables each stakeholder to provide their separate assessment on the impact of decision items upon the value factors. It can be done either synchronously, during a joint meeting, or asynchronously (e.g. in preparation to a joint meeting). Once all stakeholders provide their input, such data is aggregated and available using several data visualization charts (see Fig. 2). These charts aim to support decision-making discussions, until a final decision is reached (see Fig. 3). Further details on the VALUE tool (e.g. its architecture and detailed functionality) is given in [5]. The tool also provides the means to record group decisions, and to keep a history of decisions, thus supporting transparency and promoting organization learning.

The decision-making process implemented in the VALUE tool is supported by the "4+1" Theory of Value-Based Software Engineering [1], with the success-critical stakeholder (SCS) at the center of the win-win Theory W [17]. The identification of the SCSs is the first step, before taking the VALUE tool into use. The individual assessment explicitly represents how the SCSs want to win, and the dashboard provided by the VALUE tool aggregates all different views from the SCSs enabling the negotiation of a win-win set of product and process plans. Finally, the final decision screen provide means to record the group decisions, bringing transparency and promoting organizational learning.

In past studies the VALUE tool's usability has already been assessed [5], as it plays an important role towards technology adoption. Furthermore, several pilot/case studies have also been carried out with our industrial partners (e.g. [3]), where it was used in feature-selections contexts for different types of products.

IV. Method

The three case studies detailed herein follow the case study research method guidelines proposed by Runeson and Höst [18]. Therefore, the following steps were used: preparation of studies' protocols, selection of usage scenarios, subjects' selection, data gathering, data synthesis and reporting.

The case studies were carried out in three different decision-making scenarios: i) features selection for sprints, ii) prioritization of test cases, and iii) user interface designs' selection. The first scenario was split up into two different scenarios of use, where the same group of stakeholders, using the same set of value factors, employed the VALUE tool for features' selection for two different products.

A total of six hours of focus group meetings were carried out with the key stakeholders in order to elicit value factors, Further, thirteen decision-making meetings took place using the VALUE tool, totalizing 102 person-hours of effort.

The research protocol applied to all three case studies is presented next.

A. Research Questions

The goal of all three case studies was twofold: first, to investigate to what extent the VALUE tool can help the Embedded Laboratory improve their current value-based decision-making process; second, to assess the likelihood of success of the VALUE tool at the Embedded Laboratory. These goals led to the following research questions:

- RQ 1) To what extent did the VALUE tool help the Embedded Laboratory improve their decision-making process?
- RQ 2) What is the likelihood of success of the VALUE tool within the Embedded Laboratory's contexts of use?

B. Cases Selection

1) Case A: A group of five key stakeholders – one product owner, three developers and a Web designer, used the VALUE tool to support decisions relating to the selection of user interface designs to be implemented in "Project A". The VALUE tool was used during the decision-making meetings where the prototype of the user interfaces was uploaded in the tool as "decision items." All the five stakeholders assessed each user interface prototype accordingly to the value factors (see Table V). After each meeting, the stakeholders would decide which user interface was ready to be implemented, and which user interface needs to be improved.

"Project A" is a Web-based project management application that supports continuous improvement of the development process used by teams using Scrum. It includes the creation and maintenance of projects, support to Sprint Retrospective meetings, management of impediments, data input related to the development process, visualization of results calculated by a Bayesian network, where such results relate to the development process, improvement plan management and documentation of lessons learned.

Regarding "Case A", we had one focus group meeting to elicit the value factors, leading to 4 person-hours of effort. The VALUE tool was used across five meetings (each meeting lasted for one hour) totalizing 21 person-hours. Note that some of the developers did not participate in all meetings.

2) Case B: A group of four key stakeholders – two managers, a developer and a tester, used the VALUE tool to support decisions relating to the prioritization of the most important test cases representing the parts of "Project B" most susceptible to generate a bug.

"Project B" is a mobile application to run in the Android platform, allowing its users to visualize nearby events such as concerts, movies, parties and so on. This application also allows for users to create their own events, broadcasting to other users of the application. The application is part of a larger project, which also includes a Web application.

We conducted two focus groups to identify the value factors for the "Case B", totalizing 13 person-hours of effort. The stakeholders used the VALUE tool in four different meetings to prioritize the execution of test cases; each meeting lasted for one hour, so leading to 16 person-hours of effort.

3) Case C: A group of three key stakeholders – two managers and a product owner, used the VALUE tool to support decisions relating to features selection for the next sprint, for two different Internet of Things (IoT) projects. Due to the similarities of the products and the overlapping development team in both projects, the three key stakeholders employed together the same decision-making process and value factors across the two projects for which features had to be selected.

The first project, "Project C", is an IoT application to remotely control the watering of plants through a mobile application. It involves the development of a Web server, mobile application and implementation of sensors to monitor the plants' water level. The second project, "Project D", is also an IoT application aimed at monitoring and controlling the water level and flow of water tanks. Such management is done through a mobile application.

Both project teams work with Scrum, where each sprint lasts for two weeks. At the end of each sprint, postmortem meetings are held to discuss progress, the previous sprint's status, and to select the features to be implemented in the subsequent sprint.

Regarding "Case C", the value factors were identified in a two hours focus group meeting, so leading to 6 person-hours of effort. The key stakeholders used the VALUE tool across three decision-making meetings – two meetings for "Project C" and one meeting for "Project D", totalizing 9 person-hours of effort.

C. Subjects Selection

The studies' subjects were chosen based on their availability and the range of ongoing projects being developed at the Embedded Laboratory. Prior to using the VALUE tool, the first and third authors carried out focus groups meetings with all key stakeholders, arranged per project, in order to elicit the value factors they jointly use in their respective project's decision-making process.

1) Case A: The five stakeholders' demographic data is shown in Table I. Most participants had an average age of 24 years, and had between 1 to 3 years of professional experience with software-related activities.

2) Case B: With regard to the four stakeholders who participated in "Case B" (see Table II), they had a mean age of 26.75 (SD = 2.21) years. Most stakeholders had between 1 to 3 years of professional experience with software-related activities.

3) Case C: The three stakeholders' demographic data is shown in Table III. The mean age of the participants are 28.3 (SD = 1.53) years. Most stakeholders had between 1 to 3 years of professional experience with software-related activities.

TABLE I
CASE A'S DEMOGRAPHIC DATA

Demographic Category	Results	
Age	Mean	23
	Standard Deviation	3.46
Education Level	M.Sc. in Computer Science	1
	Undergraduate in Design	1
	Undergraduate in Computer Science	3
Professional Experience	1-3 years	4
	4-6 years	1
Project role	Software Developer	3
	Project Manager	1
	Designer	1

TABLE II
CASE B'S DEMOGRAPHIC DATA

Demographic Category	Results	
Age	Mean	26.75
	Standard Deviation	2.21
Education Level	M.Sc. in Computer Science	2
	Undergraduate in Computer Science	2
Professional Experience	Less than 1 year	1
	1-3 years	3
Project role	Software Developer	1
	Project Manager	2
	Software Tester	1

TABLE III
CASE C'S DEMOGRAPHIC DATA

Demographic Category	Results	
Age	Mean	28.3
	Standard Deviation	1.53
Education Level	M.Sc. in Computer Science	2
	B.Sc in Computer Science	1
Professional Experience	Less than 1 year	1
	1-3 years	2
Project role	Software Developer	1
	Project Manager	2

D. Data Collection

We gathered the data used to answer the research questions in three different ways, as follows: i) observational data collected during decision-making meetings; ii) postmortem interviews with all stakeholders; and iii) data from the UTAUT questionnaire (answered by all the stakeholders).

1) Observational Data: We gathered the observational data during the decision-making meetings using a word processor software. Information related to the date and time of the meetings, the attendees, the number of decision items discussed, the length of the meeting, goals, and results was documented in a structured way. Additional information relating to general comments, and tool impressions was also documented as bullet points.

2) Survey: In the post-mortem phase of the studies, we gathered participants' demographic information, and their answers to the UTAUT model questionnaire [6] using an electronic survey. The demographic part of the survey contained questions about their age, gender, academic degree, current and past roles working professionally in the information technology industry, years of experience developing software in an academic environment and years of experience working in industry. The remainder of the survey was composed of 17 questions from the UTAUT model, encompassing the users' performance expectancy, effort expectancy, social influence, facilitating conditions and behavioral intention to use the VALUE tool. All survey questions were written in Portuguese, and we also adapted the terminology and the questions formulation to fit within the three cases' context. The participants answered the questions using a 5-point Likert scale, ranging from strongly disagree to strongly agree.

3) Interviews: We conducted individual semi-structured interviews during the post-mortem phase of the studies, during the same meetings in which subjects answered the survey. The semi-structured interview script was composed by eight questions related to subjects' overall experience of using the VALUE tool. Below, an overview of the questions:

- What is your role in the project/product?
- Prior to using the VALUE tool, how were the decisions taken?
- What did you like the most about the VALUE tool?
- What did you dislike about the VALUE tool? What could be improved in the tool?
- In your opinion, did the use of the VALUE tool improve the quality of the decision-making process?
- In your opinion, did the use of the VALUE tool improve the quality of the decisions?
- Which data visualization charts, if any, were most helpful to you?
- In your opinion, what would be the main challenges/risks, if any, of employing the VALUE tool in future projects?

The interviews were recorded and later on transcribed, prior to being analyzed.

E. Data Analysis

In order to analyze the collected data, we first transcribed all the interviews and the observation notes using a word processor software. A total of 199 statements from the interviews and 78 observation notes were recorded. A coding technique [19] was used to aggregate in a spreadsheet file the statements from both interviews and observation notes. During the coding process, we wrote down field memos related to the preliminary findings. Later on, we revisited these field memos using a cross-case analysis, in order to identify similarities and differences between each case.

The original UTAUT model suggests the use of partial least squares (PLS) to analyze the data [6]. Because the PLS makes no sample size assumptions, it is also used with small samples, although such use has been discouraged [20]. Due to the

TABLE IV
SUMMARY OF UTAUT QUESTIONNAIRE RESULTS ACROSS THE THREE CASE STUDIES

Construct	Statement	Median		
		Case A	*Case B*	*Case C*
Performance expectancy	I would find the system useful in my job.	5.0	4.5	5.0
	Using the system enables me to accomplish tasks more quickly.	4.0	4.0	4.0
	Using the system increases my productivity.	5.0	4.0	4.0
Effort expectancy	My interaction with the system would be clear and understandable.	4.0	4.5	4.0
	It would be easy for me to become skillful at using the system.	5.0	5.0	5.0
	I would find the system easy to use.	4.0	5.0	4.0
	Learning to operate the system is easy for me.	5.0	5.0	4.0
Social influence	People who influence my behavior think that I should use the system.	3.0	3.5	3.0
	People who are important to me think that I should use the system.	3.0	3.5	3.0
	In general, the organization has supported the use of the system.	5.0	4.5	4.0
Facilitating conditions	I have the resources necessary to use the system.	5.0	5.0	4.0
	I have the knowledge necessary to use the system.	4.0	5.0	4.0
	The system is not compatible with other systems I use.	1.0	1.0	1.0
	A specific person is available for assistance with system difficulties.	4.0	4.5	3.0
Behavioral intention to use the system	I intend to use the system in the next months.	5.0	4.5	4.0
	I predict I would use the system in the next months.	5.0	4.5	4.0
	I plan to use the system in the next months.	5.0	3.0	3.0

TABLE V
CASE A'S ELICITED VALUE FACTORS

Group	Description
Business	Meets the user interface requirements
Technical	Implementation complexity
	Availability of third-party libraries
	Reuse potential
User Experience	Colors match the project's color pallet
	Does not have many items in the user interface
	Follows the application's default navigation
	Number of clicks to achieve the task
	User interface affordance
	User interface simplicity

small sample size, 12 respondents in total, we did not use PLS and opted to employ the collected data from the UTAUT questionnaires as support to interpreting the results from both interviews and observations.

V. RESULTS

We describe next the results from employing the VALUE tool across the three different cases.

A. *Case A*

The five stakeholders used the VALUE tool to support the selection and evaluation of user interfaces in "Project A". Table V presents the ten value factors identified in the focus group elicitation meeting, distributed amongst three different groups: business, technical and user experience.

Stakeholders evaluated the 17 statements from the UTAUT model using a 5 point Likert scale (1 = strongly disagree and 5 = strongly agree). Table IV presents the results of each case study. Regarding stakeholders' performance expectancy, the majority found the VALUE tool useful in their jobs and that the tool increased their productivity. Stakeholders also answered positively to the effort expectancy, suggesting that the tool was easy to use, and it would be easy for them to become skillful at employing it. Concerning the social influence, stakeholders neither agreed nor disagreed that people who influence their behavior and people who are important to them encourage the usage of the tool. On the other hand, they answered positively to the organization being supportive of the VALUE tool's use. Stakeholders also answered that they have the resources and knowledge necessary to use the tool and that the tool is compatible with other systems they use. The majority of stakeholders demonstrated the intent of keep using the VALUE tool, answering positively about planning to use the tool in the next months.

During the interviews, stakeholders mentioned that the decisions related to user interface were ad hoc before using the VALUE tool. All five stakeholders reported improvements both in the quality of the decisions and in the quality of the decision-making process. Further, they also reported the following positive aspects: (i) the VALUE tool made the decision-making process more systematic; (ii) the team started to have more regular meetings due to using the VALUE tool; (iii) the VALUE tool made the decisions more democratic for involving more stakeholders; (iv) the VALUE tool was easy to use; (v) the VALUE tool enabled more focused meetings. Regarding the negative aspects, stakeholders mentioned the lack of guidance on how to use the different options of data visualization, and also the lack of help pages.

The abovementioned results suggest that the VALUE tool performed well within the context of "Case A". Stakeholders had a clear understanding of the value factors, and after each meeting, they felt more confident about using the tool. In this

TABLE VI
CASE B'S ELICITED VALUE FACTORS

Group	Description
Business	Business value of the functionality
Effort	Ease of test execution
Technical	Potential to generate bug

TABLE VII
CASE B'S NUMBER OF BUGS PER USE CASE

User Case	Number of Bugs	Ranking in the Value Tool
UC12 - Invite friends	2	1
UC01 - Login	1	2
UC18 - Notify nearby friends	1	7
UC19 - Download event	3	8
UC31 - View event map	1	11

particular case, we also noticed that stakeholders with the same role provided very similar individual assessments, which may suggest that the diversity of stakeholder's roles may turn out to be more important than the number of stakeholders.

B. *Case B*

Regarding "Case B", we had two focus group meetings to elicit value factors. The first meeting was led by the first and third authors, whereas the second was led by the first and second authors. There were two focus group meetings because the value factors elicited in the first meeting had to be revisited after being used in the first decision-making meeting. Table VI shows the final set of value factors. These three value factors relate respectively to business, effort and technical aspects of the test cases.

The results from the UTAUT questionnaire (see Table IV) are very similar to those for "Case A". In relation to their performance expectancy, stakeholders agreed that the VALUE tool could be useful and increase their productivity. They felt very confident about becoming skillful with the VALUE tool and thought the tool was easy to use. Further, they agreed about the company being supportive in relation to using the tool. Concerning the facilitating conditions, stakeholders strongly agreed that they have all the knowledge and resources necessary to use the tool. The main difference in the results, compared to "Case A", relates to their intention to keep using the VALUE tool in the next months: stakeholders neither agreed nor disagreed. We do believe the reason for such answer was because "Project B" was in its final stage, with no future enhancements planned.

During the interviews, stakeholders mentioned that they had no previous experience prioritizing the execution of test cases. When asked about the quality of the decisions and the quality of the process, two stakeholders could not tell for sure, mainly because they had no parameter to compare against. The other two stakeholders said the experience of using the tool was valid and they could see the benefits of having tool support to guide their decisions.

TABLE VIII
CASE C'S ELICITED VALUE FACTORS

Group	Description
Learning	Feature involve implementation of sensors
	Learning curve
	Positive impact towards the motivation of the team
Customer	The functionality is part of the core of the software
	Importance of the functionality for the customer
	Return on investment
	Viability to become a product
Technical	Compliance with the sprint schedule
	Part of a functionality already started
	Existing artifacts related to the user interface
	Complexity of the functionality
	Pending on the results from the last sprint
	Feature is mandatory (other features depend on it)

When asked about the positive aspects of using the tool, stakeholders mentioned: (i) the VALUE tool was easy to use; (ii) the VALUE tool made decisions more pragmatic by using previously identified value factors. In relation to the negative aspects, the comments were: (i) the lack of help pages; and (ii) whenever there are numerous decision items to assess at once, stakeholders found it tedious and time-consuming.

Even though it was the first time these stakeholders were prioritizing test cases, the results from using the VALUE tool were very good. The quality assessment team tested "Project B" using the priority order provided by Case B's stakeholders using the VALUE tool. From a total of 43 use cases, only five had bugs. Table VII presents the number of bugs from each use case, and the ranking the stakeholders gave using the VALUE tool. Surely one cannot assert that such results were also due to using the VALUE tool; however, such hypothesis cannot be ruled out either.

C. *Case C*

Regarding "Case C", a two-hour focus group took place with all stakeholders, led by the first and third authors. Table VIII presents the thirteen value factors, relating to business, effort and technical aspects of the test cases.

The results from the UTAUT questionnaire (see Table IV) show that stakeholders strongly agreed that the VALUE tool is useful in their job and that it would be easy for them to be skillful at using the VALUE tool. Regarding the social influence and facilitating conditions, stakeholders were conservative in their answers. They agreed that they have the resources and knowledge necessary to use the VALUE tool, but stayed neutral when answering that a specific person is available to assist with difficulties. Similar to "Project B" in the "Case B", "Project C" and "Project D" were also in their final stage. We therefore believe that this explains why stakeholders did not agree that they planned to use the VALUE tool in the next months.

In relation to the interviews, stakeholders answered that the decisions taken prior to using the VALUE tool were done informally and without tool support. They had meetings every two weeks with the product owner and the development team to prioritize features in the backlog. When asked if they observed improvements in the quality of the decisions, they answered that they only had a few items left in the backlog, and the tool only confirmed their views. When asked about improvements in the quality of the process, all the three stakeholders answered positively.

Regarding the positive aspects of the VALUE tool, they mentioned: (i) the tool was easy to use and (ii) the VALUE tool made decisions more pragmatic by using previously identified value factors. In relation to the negative aspects, two stakeholders felt that they did not use the VALUE tool enough to observe negative aspects, and the other stakeholder mentioned that the VALUE tool requires the assessment of decision items by at least two stakeholders, for the aggregated data to make sense, and occasionally there is only a single stakeholder available to decide.

VI. Discussion

The two research questions introduced in Section IV are presented and discussed next.

A. *RQ 1) To what extent did the VALUE tool help the Embedded Laboratory improve their decision-making process?*

To answer this research question, we use as the first source of evidence the two questions asked during the interviews.

When asked whether using the VALUE tool improved the quality of their decision-making process, 83.3% (10) of all key stakeholders answered that the VALUE tool improved their decision-making process. The remaining 16.7% (2) answered that they could not tell for sure if there was any improvement. A total of 25% (3) of the key stakeholders attributed the improvement to the fact that the VALUE tool enables a larger number of stakeholders to participate in the decision-making process, thus providing an opportunity for a wider range of opinions, and a more democratic process. Further, stakeholders also mentioned that improvements in the process could also be attributed to using a tool that supports a more systematic decision-making process. Even though stakeholders may not use all the value factors, the VALUE tool also serves as a reminder of what is important to take into account while making a decision. The stakeholders that were unsure whether there was any improvement in the decision-making process were part of "Case B". However, note that they used the VALUE tool for a shorter length of time, when compared to the stakeholders in the other two cases. Perhaps such short exposure to using the VALUE tool may have contributed towards their assessment.

In relation to observing any improvement in the outcome of decisions, 50% (6) of the stakeholders answered that they observed an improvement, 33.3% (4) said the results would have been the same without the tool, and the remaining 16.7% (2) could not say anything for sure. All the 33.3% (4) stakeholders who answered that the results would have been the same without the tool, employed it in a final stage of their ongoing projects, where the set of decision items to choose were more or less stable and easy to decide upon. Thus the tool's results only confirmed their intuitive views.

During the interviews, we have also asked stakeholders about the positive and negative impressions relating to the VALUE tool. Following, the positive impressions mentioned by the stakeholders and the number of times the statement was mentioned during the interviews:

- The team started to have more regular meetings due to using the VALUE tool (3);
- The VALUE tool made decisions more pragmatic by using previously identified value factors (3);
- The VALUE tool made the decision-making process more systematic (2);
- The decision-making process became more democratic (2);
- The VALUE tool provided the flexibility to have asynchronous individual assessment (1);
- The VALUE tool provided more focused meetings (1).

In relation to the negative impressions, stakeholders reported the following:

- Lack of help pages (3);
- The wide range of charts available to visualize the aggregated data were confusing to use without guidance on how to interpret these charts (1);
- Whenever there are numerous decision items to assess at once, stakeholders found it tedious and time-consuming (1);
- The VALUE tool requires the assessment of decision items by at least two stakeholders in order for the data presented in the dashboard to be more meaningful (1).

Overall, with regard to positive impressions, stakeholders suggested that the VALUE tool provided means to improve the decision-making process (systematic and democratic process), improve decision-making meetings (more regular, asynchronous, more focused), and also the quality of decisions (more pragmatic).

As for negative impressions, they related to existing functionality (dashboard charts) and missing functionality (help pages), and also included two aspects that we see as not genuinely related specifically to using the VALUE tool – the choice of decision items to decide upon as part of a meeting, and the number of stakeholders to make decisions. The former would be time consuming regardless of using tool support or not, and the latter is indeed a requirement for having at least two voices heard during a decision-making process.

Based on the results from the three case studies, we observed that the VALUE tool performed better in decision-making scenarios related to selection problems, rather than in prioritization problems. However, note that the case in which there was the prioritization of items – "Case B", stakeholders had no previous experience in such type of decision, which could have influenced their assessments and perceptions.

B. RQ2) What is the likelihood of success of the VALUE tool within the Embedded Laboratory's contexts?

To answer this research question, we gathered data from the individual interviews and also using a survey instrument based in the UTAUT model. Even though the survey sample data was not large enough to enable a more in-depth analysis, the collected information was very useful, providing in many cases a cross-validation of the findings.

During the interviews, we asked what would be the main challenges and risks of using the VALUE tool in future projects. Time constraints and key stakeholders availability were the most common answers, given in 41.7% (5) of the interviews. On the other hand, while answering the survey, 83.3% (10) of respondents answered positively (either agree or strongly agree) to the statement "Using the system enables me to accomplish tasks more quickly", and 91.6% (11) strongly agreed or agreed with the statement "Using the system increases my productivity". We also observed this fact during a decision-making meeting employing the VALUE tool, where the stakeholders used its capabilities to eliminate decision items with high negative impact and focused upon the most important items only. Stakeholders were able to reach a consensus quickly with a satisfactory result. Also, during the interview, one of the stakeholders reported that the tool helped the group maintain the focus of the meetings on the topics they were discussing, thus a gain in productivity.

The ease of use of a software solution plays an important role towards technology adoption [16]. In the interviews, we asked stakeholders about the positive aspects of the tool. Six stakeholders mentioned that the tool is easy to use. Also, in the UTAUT survey, 83.3% (10) of the respondents strongly agreed or agreed with the statement: "I would find the system easy to use". This also supports results from past studies, where we assessed and improved the usability of the VALUE tool [5].

Regarding the behavioral intention of use, 50% (6) of the stakeholders answered that they neither agreed nor disagreed with the statement: "I plan to use the tool in the next months". The main reason might be related to the fact that the projects investigated in "Case B" and "Case C" were in a final stage. However, analyzing the answers from the stakeholders in "Case A", 83.3% (10) strongly agreed with the statement. In fact, this particular group continued using the VALUE tool in their meetings even after the case study ended.

C. Implications for Research and Practice

Results from all three case studies suggest that software companies presenting contexts similar to the ones described herein may improve their decision-making process via tool support, such as the VALUE tool. The observed improvements in the decision-making process throughout the three case studies can be attributed to the fact that using the VALUE tool made their process more pragmatic; they employed a pre-defined decision criteria (value factors), followed by individual and then group decisions.

Results showed that the VALUE tool supported more democratic decisions by enabling the participation of a wider number of stakeholders in the decision-making process. Further, tool support made it easier for stakeholders to have more focused and regular meetings, improving team's communication and ensuring everyone was on "the same page". Some of the results also suggested that the diversity of stakeholders' roles (e.g. product owner, sales person, software developer) might be more important than the number of stakeholders, as stakeholders with the same role may provide very similar individual assessments.

Results also support that the elicitation of value factors, the use of the VALUE tool and its capability to document past decisions, and to have more regular meetings due to such tool support were considered as beneficial aspects to the stakeholders at the Embedded Laboratory. Our results suggest that other companies with a similar setting as that for the company case may also benefit from using such a tool.

The VBSE community can also benefit from the results presented herein, as they add to the existing body of knowledge of VBSE tools, and in addition it presents the results from using a tool that enables the representation of stakeholders' value propositions, and individual as well as group decisions, amongst other features.

VII. Threats to Validity

According to Runeson and Höst [18], case studies can have four types of validity threats: internal, external, construct and reliability. Internal validity relates to confounding factors that may bias results if not accounted for. Within the context of this work, stakeholders' decision-making experience in the chosen decision scenarios, and motivation to use the VALUE tool could have influenced the quality of their decisions and their overall assessment relating to the VALUE tool.

To mitigate this threat, prior to deciding upon decision scenarios to use with the VALUE tool, we carried out a workshop with all the stakeholders, where the VALUE tool was introduced, followed by a brainstorming activity in which different decision scenarios to use were suggested, Except for "Case C", the decision scenarios chosen represented scenarios regularly carried out the stakeholders, and for which they clearly had prior experience. With regard to "Case C", the choice of decision scenario was motivated by its importance, rather than previous decision-making experience. However, despite their lack of experience, the ranking that stakeholders provided using the VALUE tool to prioritize the test cases was in conformance with the bugs which were reported later.

With regard to the external validity, it represents to what extent results can be generalized to a wider population. Even though all three case studies took place in a single company, this company employs a sound agile development process, where stakeholders are experienced in Scrum, and where, despite being junior developers, they are held accountable for their productivity and deliverables' quality. Also note that project managers all have industrial experience. Further, the decision scenarios also differed, and reflected different aspects within the context of software development (requirements prioritization, test cases prioritization and user interface design selection). Finally, each case study was applied to a project with a different client (i.e., company) and for different purposes.

Construct validity represents to what extent what is being measured genuinely represents what is meant to be measured. To mitigate this threat, for all cases, we used two data collection approaches: a questionnaire and semi-structured interviews. The questionnaire used has been proposed and validated elsewhere, and represents a consolidated approach to assess software solutions. Furthermore, the interview questions employed were proposed by the first author and assessed for completeness by the third author. Such approach also mitigated the reliability threats, which relates to researcher bias.

VIII. Conclusions and Future Work

In this paper, we presented the results from three case studies carried out in the Embedded Laboratory in Brazil, where a Web-based tool – the VALUE tool, was used to support their decision-making process. This tool was used by different stakeholders groups, making decisions relating to the selection of features for the next sprint, prioritization of test cases and selection of user interface designs.

The objective of this paper was to empirically investigate the usefulness of the VALUE tool in different decision-making scenarios and to measure stakeholders' tool acceptance and the effects of employing such tool in their decision-making process.

After the continuous and subsequent use of the VALUE tool throughout six weeks, we gathered observational data, and data via semi-structured interviews and structured questionnaires.

The results shown herein suggest an improvement in the decision-making process and the quality of the decisions of the investigated company. The improvement is attributed to the decision-making process becoming more systematic with the use of such tool. Regarding the likelihood of success of the VALUE tool, preliminary results suggest a positive behavioral intention of use. However, more empirical studies are needed and are planned to take place as part of our future work.

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