

Understanding the Decision-Making of Students in Requirements Engineering Course Projects

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Abstract

Decision-making is an essential part of Requirements Engineering (RE). RE can be considered as a decision-making process about the functionality and quality of the software product to be constructed. Decision-making behaviors in RE have a significant impact on the quality of requirements artifacts. Thus, it is critical to understand how stakeholders make decisions in RE. However, little empirical research has been conducted regarding decision-making in RE process. To this end, we conducted a study with 70 master students on software engineering in RE course projects. Through this study, we found that students rarely realized that they were making decisions in RE, but we identified how students made decisions in RE process by the questionnaires and work reports. We provided empirical evidence about how students made decisions in a complete RE project. Furthermore, we gained insight about the decision-making characteristics of students during requirements elicitation, analysis, validation, negotiation, and documentation.

1 Introduction

RE and architecting are two closely related phases in software development [Nus01], and a large number of decisions are made by stakeholders during RE [Aur03] and architecting [Jan05]. Despite that architecture decisions [Sha09] and decision-making in architecture [Tan17] have been widely studied, there is little understanding about how stakeholders make decisions in RE process. RE can be viewed as a decision-making process [Aur03]. Decision-making behaviors in RE have a significant impact on the quality of requirements artifacts [Ols18]. Two essential factors in decision-making are a set of alternatives and a set of criteria to evaluate the consequences of each alternative [Ngo05]. Existing work mainly focuses on various aspects of decision-making in RE instead of investigating decision-making in RE process as a whole. Decision-making is not easy and challenging in RE process, especially for junior software engineers, and there are many factors that affect decision-making in RE, such as dynamic environment, time stress, and multiple players [Ora93]. To help stakeholders make decisions in RE, we should first understand how they make decisions. In this work, we took the first step and conducted a study with master students on software engineering, aiming to understand their innate decision-making in RE process through their RE course projects.

The rest of this paper is structured as follows: Section 2 discusses related work. Section 3 describes the research method in detail. The results of the study are presented in Section 4 and discussed in Section 5. Section 6 describes the threats to validity, and Section 7 concludes this work with future directions.

2 Related Work

2.1 Activities in Requirements Engineering

Aurum and Wohlin declared that RE is not only an organizational process, but also a project process. They proposed that managing the RE process is of great importance to the successful development of software products [Aur03]. Sommerville proposed six RE activities as components of integrated RE, which are fundamental to all RE processes: elicitation, analysis, validation, negotiation, documentation, and management. He also indicated that RE is an iterative process, in which individual RE activities repeat as requirements are derived [Som05]. An RE process is composed of a set of activities, and we intend to understand decision-making in RE from the RE activities perspective. We assume that decision-making may have different characteristics in various RE activities.

2.2 Decision-Making in Requirements Engineering

RE can be considered as a decision-making process about the functionality and quality of the software product to be constructed [Aur03]. Decision-making in RE is an activity including much intensive knowledge [Aur03]. Ngo and Ruhe declared that decision-making is solving a decision problem by analyzing a set of alternatives with different criteria in order to choose a solution. They argued that a decision problem contains the description of the problem, a set of corresponding alternatives, and the evaluation of these alternatives at least [Ngo05]. These studies cover various aspects of decision-making in RE, but there is a lack of research on decision-making in an RE process perspective. Our work was conducted from the perspective of RE activities (see the discussion in Section II.A) in order to have a more comprehensive and detailed understanding of decision-making in RE process.

3 Research Method

3.1 Goal and Research Questions

Many decisions are made during the process of RE. The goal of the study is to get insight into the innate decision-making that students follow in the processes of RE [Som05]. To this end, we conducted a study in order to understand how students make decisions in RE process as the first step. Sommerville argued that an RE process is basically composed of six RE activities: elicitation, analysis, validation, negotiation, documentation, and management [Som05]. Due to the time limitation of the RE course project (see Section 3.3 about the case study procedure), we did not ask the students to manage their requirements, consequently requirements management activity was not considered in this study. We refine the research goal into five Research Questions (RQs) according to the rest five RE activities:

RQ1: How do students make decisions during requirements elicitation?

RQ2: How do students make decisions during requirements analysis?

RQ3: How do students make decisions during requirements validation?

RQ4: How do students make decisions during requirements negotiation?

RQ5: How do students make decisions during requirements documentation?

Rationale: Requirements elicitation is the first step in RE, and this activity provides the foundation for other RE activities. Requirements analysis can help stakeholders understand requirements and their relationships (e.g., their overlaps and conflicts). Requirements validation is an essential part of RE, which can help to identify what requirements are really needed by stakeholders. In requirements negotiation, stakeholders communicate with each other frequently and require a large number of trade-offs in order to get the requirements that all stakeholders agree. Requirements documentation impacts the quality of software products to a great extent. With these five RQs, we want to understand the characteristics of decision-making of students during the five RE activities when they finish their RE course projects.

3.2 Case Description

To answer the RQs, we conducted a case study with 70 master students on software engineering in the RE course at Wuhan University during the autumn semester from 20/09/2017 to 29/11/2017.

3.3 Case Study Procedure

Step 1: Preparation

Each group proposed a software project, and made a bid for a project proposed by another group. The proposed 17 projects were reviewed by the researchers (i.e., the authors), to ensure that the projects were meaningful, non-trivial, and different from each other. (all the project information has been provided in [Liu18]). The researchers prepared the case study design and the tutorial about decision-making, and collected background information from each subject through a questionnaire. The researchers gave a tutorial to help the subjects understand the concept of decision-making

and gave the lecture about RE process and activities. The researchers also had a discussion with the subjects regarding these two topics after the tutorial to make sure that the subjects had a sufficient basis to conduct the case study.

Step 2: Execution

The subjects started their RE course projects. We provided the groups a work report template (see [Liu18]) for reporting their decision-making in projects. Every two weeks the groups were asked to submit a new iteration of their work reports.

Step 3: Data collection

In the last week of the course, each group was asked to fill in a questionnaire, which was used to answer the RQs.

3.4 Data Collection

Two data collection methods are used in this case study: questionnaire and work report. The questions in the questionnaire and the template of the work report are provided in [Liu18].

Questionnaire. In order to enable students to experience decision-making in RE, we asked them to work on an RE course project. By the end of the project, the students were asked to fill in a questionnaire which reports about their group decision-making experience. Questionnaire was designed according to the design principle in [Let05]. We reviewed a large number of studies on decision-making in RE and decision-making in general to help us create such questions. The questions in our questionnaire for each RE activity are 10 identical questions as provided in [Liu18]. Through the design of such a questionnaire, we try to understand the characteristics of decision-making of students in each RE activity, as well as the similarities and differences of decision-making among RE activities.

Work report. We provided a work report template (see [Liu18]) at the beginning of the course project. The work report template is composed of a set of questions related to decision-making in RE and the work reports submitted by the groups can be used as complementary material to validate the results of the questionnaire. Each group should submit a work report in each iteration (every two weeks) during the course project. The work reports produced by the groups were analyzed by the researchers to collect the information about the decision-making activities of students in the RE projects.

3.5 Data Analysis

We used descriptive statistics for analyzing quantitative answers (such as the number of the selected options) to answer the RQs, and used Grounded Theory (GT) [Gla67] for analyzing qualitative answers which generates concepts and categories from the work reports to help interpret the results of the RQs (in Section 错误!未找到引用源。). GT refers to a method of inductively generating theory from data [Gla67]. We related the codes through axial coding. In this procedure, the codes were merged and grouped into more abstract categories. Then, we used selective coding to identify core categories that best explain how students make decisions in RE process. These steps were executed in an iterative process with two of the authors (the first and fourth), and the codes with their relationships were refined and adapted in each iteration. The second and third authors were consulted to resolve any inconsistencies, and all the authors reviewed the coding results together for clarity (the coding results are provided in [Liu18])

4 Results

4.1 Results of RQ1

Single choice questions Q2, Q4, Q7, Q8, and Q10 from the questionnaire are related to the decision-making during requirements elicitation. Figure 1 shows a stacked bar chart presenting cumulative percentage frequencies of answers to the respective questions. More than 70% groups affirmed that they understood the problems to be made a decision (Q2). The answers to Q4, concerning whether they have evaluated the alternatives, do not show a clear trend. About half of the groups have a member in the group responsible for the decision-making process during requirements elicitation (Q7). About half of the groups thought that all decisions should be made by all group members (Q8). The majority of the groups (>70%) affirmed that the customer group should be actively involved in the decision-making process (Q10).

The results of multiple choice questions Q3, Q5, and Q6, mainly related to the methods adopted in the decision-making process, are provided in [Liu18]. The majority of the groups (>90%) considered adapting the existing solutions in decision-making (Q3). When evaluating decision alternatives, there is a 50% adoption rate for “scoring for alternatives” and “formulating evaluation criteria” respectively (Q5). When choosing solutions in the decision-making process, there is a 50% adoption rate for “locally optimal solutions” (the solutions that are optimal either maximal or minimal within a neighboring set of candidate solutions) and “globally optimal solutions” (the optimal solutions among all possible solutions) respectively (Q6).

The results of the open-ended question Q1 show that the groups usually make decisions on stakeholder analysis, determining the sources of requirements, as well as functional requirements during requirements elicitation. Q9 demonstrate that some groups believed that all the problems need decision-making during requirements elicitation, but other groups thought that some issues do not need decision-making (e.g., method of communicating with customers and prospects of the project).

In the work report, we provided a template (see [Liu18]) for the groups to record the information about their decision-making process. R1, R2, R3, R4, and R13 are related to RQ1. The groups recorded their decision-making process during requirements elicitation in the work report. Through the GT analysis, the decision-making process during requirements elicitation is usually composed of three steps: (1) proposing alternatives; (2) evaluating alternatives; and (3) selecting a solution from alternatives. This process as a general process in decision-making was also identified in the rest four RE activities. We only highlight the differences between these five RE activities in their decision-making processes. In requirements elicitation, the groups paid more attention to proposing and evaluating alternatives.

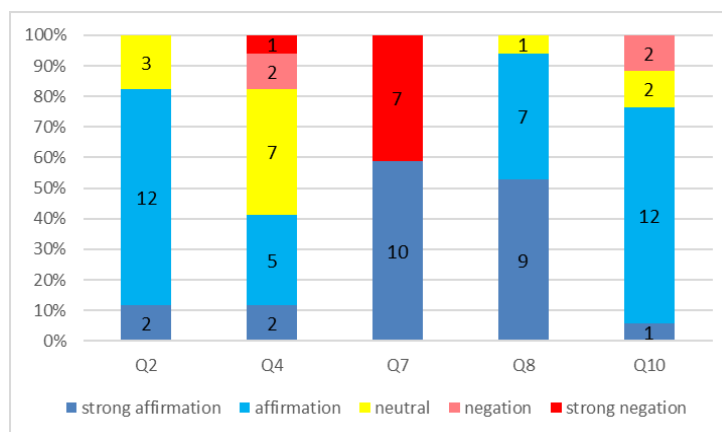


Figure 1: Cumulative frequencies of the answers to survey questions related to RQ1

4.2 Results of RQ2

Single choice questions Q12, Q14, Q17, Q18, and Q20 from the questionnaire are primarily related to the decision-making during requirements analysis. Figure 2 shows a stacked bar chart presenting cumulative percentage frequencies of answers to the respective questions. More than 70% groups affirmed that they understood the problems to be made a decision (Q12). The answers to Q14, concerning whether they have evaluated the alternatives, do not show a clear trend. The majority of the groups (>70%) have a member in their group responsible for the decision-making process during requirements analysis (Q17). About half of the groups thought that most of decisions should be made by all group members (Q18). The majority of the groups (>70%) affirmed that the customer group should be actively involved in the decision-making process (Q20).

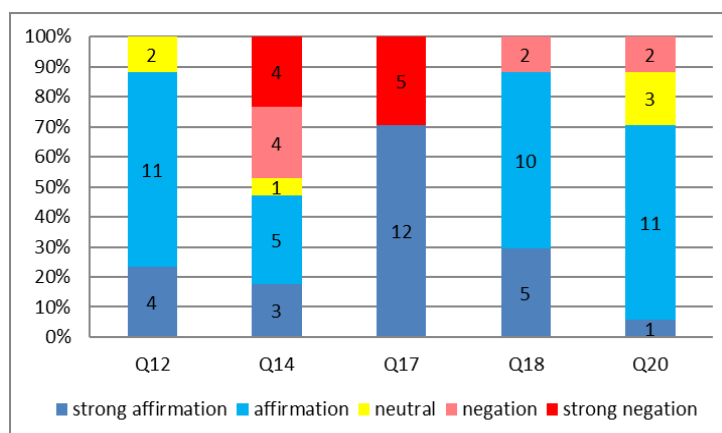


Figure 2: Cumulative frequencies of the answers to survey questions related to RQ2

The results of multiple choice questions Q13, Q15, and Q16, mainly related to the methods adopted in the decision-making process, are provided in [Liu18]. The majority of the groups (>90%) considered adapting the existing solutions in decision-making (Q13). When evaluating decision alternatives, there is a 50% adoption rate for “allocating weight for each dimension to be evaluated” and “scoring for alternatives” respectively (Q15). When choosing solutions in the decision-making process, there is a 60% adoption rate for “locally optimal solutions” (Q16).

The results of the open-ended question Q11 show that the groups usually make decisions on analyzing functional requirements and determining requirements conflicts during requirements analysis. The results of question Q19 demonstrate that most of the groups believed that certain non-functional requirements analysis (e.g., availability and security) do not need decision-making during requirements analysis, because they thought that the analysis of these non-functional requirements can follow existing standards.

In the work report, R8, R9, and R13 are related to RQ2. The decision-making process in requirements analysis is similar to that in requirements elicitation, but students usually used the methods they were familiar with when considering alternatives during requirements analysis.

4.3 Results of RQ3

Single choice questions Q22, Q24, Q27, Q28, and Q30 from the questionnaire are primarily related to the decision-making during requirements validation. Figure 3 shows a stacked bar chart presenting cumulative percentage frequencies of answers to the respective questions. More than 80% groups affirmed that they understood the problems to be made a decision (Q22). About half of the groups thought that alternatives were rarely evaluated in the decision-making process (Q24). About half of the groups have a member in their group responsible for the decision-making process during requirements validation (Q27). The majority of the groups (>70%) thought that most of decisions should be made by all group members (Q28). About half of the groups affirmed that the customer group should be actively involved in the decision-making process (Q30).

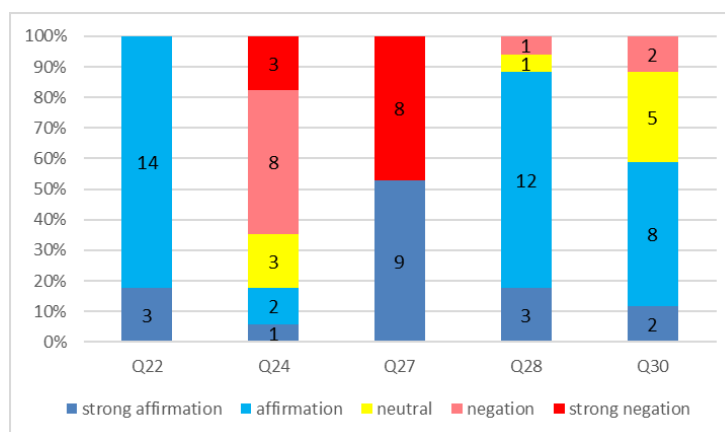


Figure 3: Cumulative frequencies of the answers to survey questions related to RQ3

The results of multiple choice questions Q23, Q25, and Q26, mainly related to the methods adopted in the decision-making process, are provided in [Liu18]. The majority of the groups (>90%) considered adapting the existing solutions in decision-making (Q23). When evaluating decision alternatives, there is a 40% adoption rate for “formulating evaluation criteria” (Q25). When choosing solutions in the decision-making process, there is an 80% adoption rate for “locally optimal solutions” (Q26).

The results of the open-ended question Q21 show that the groups usually make decisions on the priority of requirements to be validated during requirements validation. The results of question Q29 demonstrate that some groups believed that certain non-functional requirements validation (e.g., availability and security) do not need decision-making during requirements validation, because they thought that the validation of these non-functional requirements can follow existing standards.

In the work report, R5, R12, and R13 are related to RQ3. More alternatives are proposed (i.e., Step (1) in the general decision-making process) for evaluation during requirements validation, because students hope for a better solution with more comprehensive alternatives.

4.4 Results of RQ4

Single choice questions Q32, Q34, Q37, Q38, and Q40 from the questionnaire are primarily related to the decision-making during requirements negotiation. Figure 4 shows a stacked bar chart presenting cumulative percentage frequencies of answers to the respective questions. About half of the groups affirmed that they understood the problems to be made a decision (Q32). About half of the groups thought that alternatives should be evaluated in decision-making process (Q34). The majority of the groups (>70%) have a member in their group responsible for the decision-making process during requirements negotiation (Q37). The majority of the groups (>80%) thought that most of decisions should be made by all group members (Q38). The majority of the groups (>70%) affirmed that the customer group should be actively involved in the decision-making process (Q40).

The results of multiple choice questions Q33, Q35, and Q36, mainly related to the methods adopted in the decision-making process, are provided in [Liu18]. The majority of the groups (>80%) considered adapting the existing solutions in decision-making (Q33). When evaluating decision alternatives, there is a 60% adoption rate for “scoring for alternatives” (Q35). When choosing solutions in the decision-making process, there is a 60% adoption rate for “locally optimal solutions” (Q36).

The results of the open-ended question Q31 show that the groups usually make decisions on determining the approaches of solving ambiguity or conflicts during requirements negotiation. The results of question Q39 demonstrate that some groups believed that negotiation of the core functional requirements which were most-wanted by customers does not need decision-making during requirements negotiation, because these requirements should be implemented and decisions on whether or not to include these requirements are not necessary.

In the work report, R6, R10, R11, and R13 are related to RQ4. When there are conflicts on decision-making results within a group, they usually choose the solution by voting during requirements negotiation.

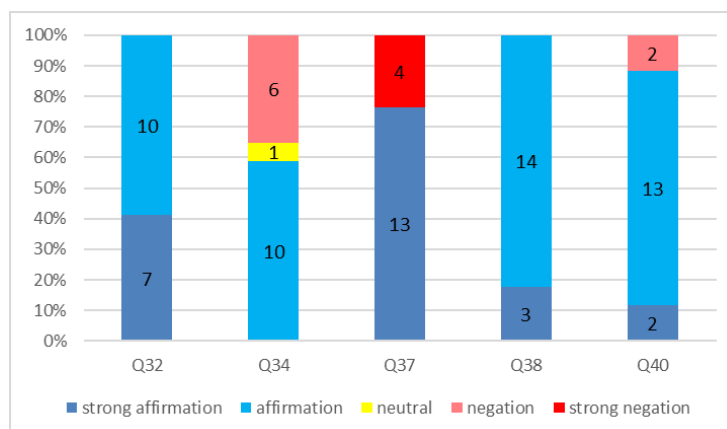


Figure 4: Cumulative frequencies of the answers to survey questions related to RQ4

4.5 Results of RQ5

Single choice questions Q42, Q44, Q47, Q48, and Q50 from the questionnaire are primarily related to the decision-making during requirements documentation. Figure 5 shows a stacked bar chart presenting cumulative percentage frequencies of answers to the respective questions. The majority of the groups (>80%) affirmed that they understood the problems to be made a decision (Q42). About half of the groups thought that alternatives were rarely evaluated in decision-making process (Q44). About half of the groups have a member in their group responsible for the decision-making process during requirements documentation (Q47). About half of the groups thought that most of decisions should be made by all group members (Q48). The answers to Q50, concerning whether the customer group should be actively involved in the decision-making process, do not show a clear trend.

The results of multiple choice questions Q43, Q45, and Q46, mainly related to the methods adopted in the decision-making process, are provided in [Liu18]. The majority of the groups (>70%) considered adapting the existing solutions in decision-making (Q43). When evaluating decision alternatives, there is a 70% adoption rate for “scoring for alternatives” (Q45). When choosing solutions in the decision-making process, there is a 60% adoption rate for “globally optimal solutions” (Q46).

The results of the open-ended question Q41 show that the groups usually make decisions on determining the content of requirements documentation, as well as requirements documentation priority during requirements documentation. The results of question Q49 show that some groups believed that the parts that do not change in documentation do not need decision-making during requirements documentation.

In the work report, R7 and R13 are related to RQ5. The groups thought that there were very few problems that require decision-making, because they argued that requirements documentation can follow the existing standard (e.g., ISO/IEC/IEEE 29148:2011) without many decisions to be made.

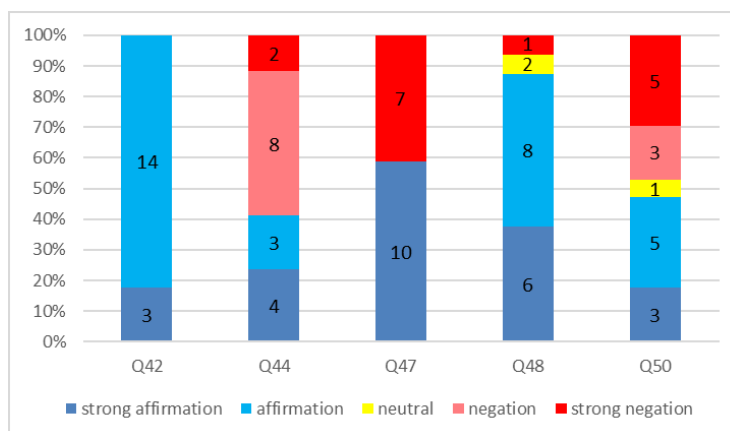


Figure 5: Cumulative frequencies of the answers to survey questions related to RQ5.

5 Discussion

5.1 Similarities in Decision-Making among RE Activities

Through the results, we can find that there are many similarities in decision-making among the five RE activities: (1) Students understood the problems to be made a decision in each RE activity. (2) Most of decisions were made with the involvement of all members in each RE activity. (3) Most students adapted the existing solutions (e.g., searching from the Internet) as alternatives for decision-making in each RE activity. (4) When choosing solutions from alternatives in decision-making, students usually considered multiple alternatives that lead to a locally optimal solution.

These similarities indicate that students tend to be cautious in the decision-making of the five RE activities. They are used to discussing with all group members when making decisions. Students rarely come up with innovative solutions when making RE decisions.

5.2 Differences in Decision-Making among RE Activities

Through the results, we can find that there are also many differences in decision-making among the five RE activities: (1) Evaluating alternatives was rarely practiced during requirements validation. (2) There was always a member in the group responsible for the decision-making processes during requirements analysis and negotiation. (3) The customers were actively involved in the decision-making processes during requirements elicitation, analysis, and negotiation. (4) The groups thought that very few problems required decision-making during requirements documentation.

These differences indicate that various decision-making practices (e.g., responsible person in the decision-making process, frequent communication with customers) are employed in RE activities depending on the characteristics and needs of the activities, as well as the experience of the students (e.g., their knowledge about the related standards).

6 Threats to Validity

Construct validity means to what extent the RQs and the studied operational measures are consistent. A potential threat is that the participants answered the questionnaire without a fair understanding of the concept of decision-making. To mitigate this threat, the participants (i.e., students) and researchers (i.e., the authors) had a discussion about the concept of decision-making (including both the concrete examples and definitions) to ensure that the participants have a fair understanding of the concept of decision-making. The other threat is that students may not have a decent understanding of the RE activities. To mitigate this threat, we had introduced RE process and activities in the first lecture of the RE course. Four students (out of 70, 5.7%) had neither participated in any software project (i.e., academic, industry, or open source projects), nor attended any course of software engineering. To maximize the randomness, we grouped the students according to their student numbers, and we ensured that these four students had been allocated to different groups, therefore the threat of having inexperienced groups has been mitigated.

Internal validity focuses on the avoidance of confounding factors that may influence the interpretation of the results of a study. There is a risk that students might impress the lecturers by giving specific answers. To mitigate this potential issue, the questionnaire was not taken into consideration for the grading of the course, and there were no correct or wrong answers to the questions in the questionnaire.

External validity concerns the generality of the study results in other settings, and it mainly depends on the employed sampling. The difference on the background knowledge between the participants can be a threat. The participants of the study were first year master students on software engineering. Their knowledge on software development is comparable to the lowest level of professionals. Thus, it can be assumed that this risk is mitigated. The course projects are not real projects from industry. To mitigate this threat, we asked the students to play the role of customers and asked them to come up with their requirements based on their knowledge and external sources (e.g., Google). However, additional constraints (e.g., time, cost, corporate culture, and politics) exist in real projects that can hardly be simulated in a classroom environment. Replicating this study in an industrial setting can address this issue.

Reliability focuses on whether the study yields the same results when other researchers replicate it. We performed a pilot study to refine the study design (e.g., the questions in the questionnaire), and reduce the ambiguities in the execution of the study. The protocol of the study and the design of the questionnaire were reviewed by the researchers iteratively, to mitigate the bias in the design of the case study and ensure the reliability of this study. Also, two authors conducted data analysis in parallel to reduce the personal bias in analysis. The study data is also available online [Liu18].

7 Conclusions

Decision-making in RE is difficult and could be different in various RE activities. In this work, we conducted a study with 70 master students on software engineering in the RE course. The main findings are: Students rarely come up with innovative solutions in RE decision-making, and they are used to making decisions through group discussion. The decision-making practices employed by students depend on both the needs of the RE activities and the experience of the students. In the next step, we plan to extend this study using industrial projects and to explore the characteristics of each RE activity in RE process. We also intend to develop a framework to facilitate the decision-making in RE process.

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