Software Requirements Triage and Selection: State-of-the-Art and State-of-Practice

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Abstract—Software requirement triage and selection in market-driven requirements engineering is a crucial activity for the success of a project, product and company. This paper presents state-of-the-art and state-of-practice in requirements triage and selection through systematic literature review and an industrial survey. Industry practitioner can read most applicable challenges and factors considered today and factors to be considered ideally to address the challenges, which have been collected through the survey. For researchers, the results show which challenges still need to be addressed.

Keywords—software requirements triage and selection; challenges; systematic review; survey

I. INTRODUCTION

In market-driven requirements engineering context (MDRE), requirements triage and selection is absolutely paramount for the success of a project, product and company [1, 2]. Triage is an early dismissal or acceptance of requirements to avoid requirements overload in later stages of product development. Thus, which features go into a product is decided during requirements triage and selection.

There has been an increased awareness within the software engineering community about the importance of empirical studies to develop or improve processes, methods and tools for software development and maintenance [3]. Several requirements triage and selection solutions have been presented in academia and as industry experience reports. The central aim of the paper is to report state-of-the-art and state-of-practice in requirements triage and selection. Through a systematic literature review (SLR), challenges related to requirements triage and factors suggested to address the challenges are identified. As a next step, the identified challenges and how they can be mitigated are used in an industrial survey to identify most applicable challenges and how are they handled today and should be handled. And last but not the least, the effects of company’s size, number of incoming requirements and requirements engineering (RE) experience of respondents on the responses are analyzed and discussed.

Industry practitioner can read most applicable challenges collected through the survey and factors considered today and factors that should be considered to address them. From an academic point of view, the list of most applicable challenges and how are they addressed today and should be addressed can be used as inputs for future industry relevant research.

The remainder of the paper is structured as follows. Section II describes the background and related work. Section Error! Reference source not found. presents the research questions and design of SLR. Section Error! Reference source not found. contains the results of SLR. Section V contains the survey design details and Section VI contains the survey results and analysis. Section VII concludes the paper with a summary and discussion.

II. BACKGROUND AND RELATED WORK

In this section the concept and purpose of requirements triage and selection are introduced. The purpose of this is 1) to provide a background to the concepts relevant for the systematic review, and 2) to describe the scope of the review.

Triage is a technique used by the medical professionals to prioritize their patients for treatment based on the symptoms of severity of the disease. In software industry, a number of researchers has proposed different criteria for performing requirements triage [6-11], e.g. requirements implementation cost, volatility, schedule slips, lack of domain experience, interdependencies and estimated effort required.

After an initial triage, requirements are analyzed and selected based on cost estimates and priorities. It is also referred to as release planning [1]. Requirements selection is often perceived as a complex task, where complexity is defined in terms of number of requirements to be considered, various technical aspects to be taken into account for requirements selection process and the challenges associated with decisions based on uncertain estimates [12].

Triage and selection is a difficult art, filled with political and financial dangers. It can be politically dangerous as both technical and marketing teams claim the task of performing the triage process as their individual responsibility. It can be financially dangerous, as a flaw in requirements triage process i.e., not including the right requirements may cause serious loss in revenues for the organization [6].

A number of studies [13-15] have reviewed the state of empirical research in requirements engineering. However, to the best of our knowledge no other study has been conducted with the same focus as the review presented in this paper. Similarly, although results of several surveys in the field of requirements engineering are reported [3, 21, 22, 23, 24, 25, 26, 27], no paper has reported results of an explicit survey in industry about prevalent requirements triage challenges and factors to handle those challenges.
III. RESEARCH QUESTIONS AND REVIEW DESIGN

This section gives a detailed description of the review design and definitions of the terms used. RQ1-RQ2 (see Table 1) are answered through systematic literature review and RQ3 is answered through the survey with industry practitioners.

Table 1 – Research questions and motivation

| RQ1 | What has been proposed in literature for requirements triage and selection? (i.e. which solutions have been proposed for requirements triage and selection process? A solution can be a method, model, tool, process, technique, or others e.g. guidelines, theory etc.) |
| Motivation | To systematically map the identified requirements triage and selection solutions according to the scheme proposed in [28]. |
| RQ2 | Which challenges have been addressed by the proposed requirements triage and selection solutions? |
| Motivation | Identify challenges addressed partially or completely by the existing solutions. |
| RQ3 | What is the state-of-practice with respect to the challenges identified in literature? |
| Motivation | Elicit state-of-practice (current and ideal) with respect to the challenges identified in literature. |

The systematic review was performed following guidelines proposed by Kitchenham and Charters [29]. Details such as population, intervention, outcomes, databases searched, search strings, inclusion exclusion criteria are available online [30]. In order to ensure that search strings are comprehensive and precise, an expert librarian was consulted.

Based on the search strategy and inclusion and exclusion criteria given at [30], study selection was performed. Since the purpose of the review is to identify all requirements triage and selection solutions in literature, any study related to requirements triage and/or requirements selection that discussed/addressed challenges related to triage and selection was included. Out of 204 primary studies identified from the search strategy, 23 studies were selected as relevant. The study selection process is available online [30]. The study selection criteria were pilot-tested by the authors on a random sample of 12 studies. The calculated Kappa co-efficient was 0.82 for the study selection process, which was deemed as sufficient.

Based on the research questions (given in Table 1), a set of data extraction categories taken from [1, 25] were used for data extraction (see [30]). Kappa co-efficient (K) for data extraction came out as 0.81 which showed strong agreement between authors.

IV. SLR: RESULTS AND ANALYSIS

This section presents an overview of included studies (Section Error! Reference source not found.) as well as the analysis of data extracted from the included studies (Section Error! Reference source not found. and Section IV.C).

A. Included Studies Overview

Summarizing the data extracted from the included studies, 17 studies out of 23 papers propose requirements triage and requirements selection solutions. Out of 17 studies, 12 studies propose requirements selection solutions while the remaining five studies propose requirements triage solutions. The remaining six studies [S6, S7, S8, S14, S19, S20], out of the selected 23; in some sense propose solutions for requirements triage and selection.

B. RQ1. What has been proposed in literature for requirements triage and selection?

A total of five solutions have been proposed for requirements triage, out of which two are methods, one is a technique, one is a process and one is a set of guidelines to be followed by the practitioners for requirements triage. For requirements selection, the authors in six studies (out of 12) have proposed some rules or guidelines to be followed by the practitioners while performing requirements selection. However, for requirements selection, no techniques and processes have been proposed. Furthermore, no automated tools or decision support has been proposed for performing requirements selection during initial stages of MDRE.

Although guidelines and methods can provide conceptual help for requirements triage and selection, an automated decision support can be beneficial as it contributes significantly in improving the ability to decide given the huge number of incoming requirements and limited time frame. Lack of automated decision support could be a major impediment in using a triage and selection solution within software requirements management.

No metrics have been proposed to assess the quality of any requirements triage and selection solutions. Metrics have the potential to provide objective information necessary for technical and managerial insight and control of effort involved in product development [33]. Without evaluation and measurement, the effect of a requirements triage solution (either positive or negative) cannot be objectively evaluated and measured. The implications being the practitioners cannot compare and select a better requirements triage solution out of the available ones. Lack of metrics and criteria for evaluation, therefore, needs immediate attention of researchers.

C. RQ2: Which challenges have been handled by the proposed solutions?

During data extraction, the challenges were labeled and coded using grounded theory approach [31] and are discussed below.

C1: Difficulty in alignment of requirements with long-term business goals

Requirement triage and selection decisions should ensure that both short-term and long-term business goals defined in the company and product strategy are realized. This can be attained by balancing different types of requirements, which are mainly categorized as current market needs/wishes/opportunities/requests (termed as market-pull) and aspirations of creating innovations (termed as technology-push) [1, 29]. However, it has been reported as a challenge to achieve this balance during requirements triage and selection. Several studies recommend a set of criteria to be used during requirements triage and selection which can help mitigate this
challenge [14, 34, 35, 36]. Thus, we asked survey respondents as to which of the stated criteria they consider today and which should ideally be considered during requirements triage to address this challenge (details in Section VI).

C2: Requirements dependencies
In order to perform requirements triage and selection, clear and understandable view of requirements and interdependencies (such as AND, OR, REQUIRE etc) between them is necessary [25, 37]. If dependencies are not considered at initial stages of requirements selection, there may be lot of expensive consequences later. For example, if it is discovered at the development stage that a requirement is missing which should be implemented before implementing a subset of selected ones; this would lead to expensive rework. However, considering different dependency relations for so many requirements at a very initial stage is a challenge. In relation to this challenge, we asked survey respondents as to which dependencies they consider today and which should ideally be considered during requirements triage to address this challenge (see Section VI).

C3: Difficulty in improving requirements triage decision quality
If decisions made during requirements triage and selection are recorded; a retrospective examination of release planning decision-making can be made, at a time when the consequences of requirements triage and selection decisions are visible. By analyzing the decision outcome in retrospect, practitioners can gain valuable knowledge of how to improve the requirements triage and selection process and increase the chances of market success [38]. However, mostly decisions related to requirements triage are not stored and thus there is a lack of knowledge base which can be used to do post-mortem analysis of decision making. Again, there are some recommendations in literature as to which decision attributes should be stored to address this challenge. In the survey, we have asked which of the attributes they store currently and which they would ideally like to store (see Section VI).

C4: Difficulty in comparing functional and non-functional requirements
Non-functional requirement are also known as quality attributes, which are restrictions or constraints on the system. Non-functional requirement refers to portability, testability, performance, security etc. The analysis and trade-off between requirements dictates the ability to balance functional requirements with non-functional aspects such as architectural longevity and maintainability [37, 39]. However, during triage, it is a challenge to compare functional versus non-functional requirements since non-functional requirements may have a scope broader than functional requirements. Through SLR, we did not find any specific mitigation strategy and or factors to be considered to address this challenge. Therefore, we did not ask respondents how this is addressed in industry.

C5: Creation of product value
It is important to do careful analysis and do trade-offs between requirements as it dictates long-term vs. short-term product development. Moreover, balancing functional requirements with non-functional aspects such as architectural longevity and maintainability are important for a product’s long-term sustainability [34]. Thus, it is a challenge to create value by balancing all these aspects.

C6: Difficulty in selection of prioritization techniques
Requirements are to be prioritized based on criteria or some technique for including them in release plan [33, 40]. There are several prioritization techniques; however, based on the context (ease-of-use, scalability, accuracy, cost-efficiency) it is difficult to chose a specific technique.

Challenges faced by the practitioners in industry may differ from challenges identified through SLR. To identify the most applicable challenges and factors used to address them today and ideally, a survey was conducted which is described in the subsequent section.

V. SURVEY DESIGN
After identifying a list of challenges and how they can be addressed, the next step was to design a survey for answering RQ3. In the survey, challenges related to requirements triage and selection were stated. The challenge C5 (creation of product value) was not considered explicitly as it is a sub-challenge of C1 and requires a more detailed investigation. Similarly, challenge C6 (difficulty in selection of prioritization techniques) was left out as it is challenge related to requirements selection. Close-ended questions were used to elicit the details of practitioners answering the survey. Likert scale was used in the survey for rating the applicability of the challenges and how they are addressed. The questionnaire was designed using a web interface (available at http://www.surveymonkey.com/s/SurveyAboutReqsTriage).

VI. SURVEY: RESULTS AND ANALYSIS
A total of 33 responses from nine different organizations in US, Sweden and India were received. Data was split from three different perspectives to investigate different possibilities. There was an outlier in survey results, where the number of incoming requirements handled per month was stated as zero. After the investigation, it was found that the person does not handle requirements in his current role but since he has a lot of RE experience his response was included.

A. RQ3. What is the state-of-practice with respect to the challenges identified in literature?
Most Applicable Challenges
The challenges which were marked “Fully applicable” or “Applicable” by the respondents were counted as most applicable challenges. These challenges in descending order of applicability are given online [30]. Based on survey responses, challenge C1 is the most commonly faced challenge while C3 is considered as the least applicable challenge. It is aligned with the results reported in literature that practitioners are constantly faced with the challenge of aligning requirements with long-term business goals especially when short-term revenues and customer satisfaction are almost premiersed over the long-term goals and objectives.

Respondents reported that considering requirements dependencies during requirements triage is a challenging job. This is understandable since during initial triage there can be far too many requirements at different abstraction levels to do an analysis and identify dependencies. However, it is central to have some idea about dependencies to avoid re-planning at later stages.
Challenges C4 and C3 are considered to be less applicable compared to C1 and C2. It could be due to the fact that organizations may already have established techniques for handling these challenges, e.g. for C4 either they have technique to compare functional and non-functional requirements during triage, or they are treated separately.

From the categorization of challenges with respect to the company’s size, number of incoming requirements and RE experience of respondents [30], it was interesting to find that C1 is considered as the most applicable challenge irrespective of the size of the organization, number of incoming requirements and RE experience except for the respondents with high experience who handle large number of requirements in small organizations. This was further confirmed by Mann-Whitney t-test for independent samples. From the two tailed significance values of t (.935, 1.00, .249 and .546) for C1, C2, C3 and C4, which are greater than 0.05, it is evident that there is no difference in applicability of C1, C2, C3 and C4 with respect to the size of the company. With respect to the number of incoming requirements, no difference was found in the applicability of the challenges except C3. With respect to the RE experience of respondents, it is also concluded that there is no difference in the applicability of challenges as the two tailed significance value of t (.841, .234, .709 and .856) for C1, C2, C3 and C4 are greater than 0.05.

It is interesting that highly experienced respondents working with less than 50 requirements per month, irrespective of the size of the organization, stated most of the challenges as applicable. Since the respondents are highly experienced this could be an indication that the existing solution(s) at the corresponding companies are not effective enough to address the challenges. Whereas, respondents with less experience might not have an extensive knowledge about the requirements triage complexity and challenges. Respondents working in small organizations did not rate C3 an applicable challenge. For small organizations handling small number of requirements, it is understandable that they can remember the earlier decisions and based on that improve the quality. However, for small organizations handling more than 50 requirements, it is practically impossible to remember all the triage decisions made earlier and improve triage quality. It could be that these companies are recording requirements decisions and using them for learning and improving triage quality.

**Requirements Criteria**

52% of the respondents responded that an explicit requirements triage criteria is used for performing requirements triage. 12 different requirements triage criteria stated in the survey are presented in Table 2 (collected through SLR).

## Table 2: Requirements triage criteria

<table>
<thead>
<tr>
<th>IDs</th>
<th>Requirements triage criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Requirements volatility</td>
</tr>
<tr>
<td>T2</td>
<td>Scope and vision of requirement</td>
</tr>
<tr>
<td>T3</td>
<td>Product domain expertise</td>
</tr>
<tr>
<td>T4</td>
<td>Implementation cost</td>
</tr>
<tr>
<td>T5</td>
<td>Interdependencies</td>
</tr>
<tr>
<td>T6</td>
<td>Time-to-market</td>
</tr>
</tbody>
</table>

**Requirements Dependencies**

From Table 3, it is evident that C-VALUE and AND are the most considered dependencies considered today and amongst the ones that should ideally be considered. However, according to the responses, more respondents would like to give consideration to D4 (REQUIRE) and D6 (I-COST).

From the analysis of responses with respect to the size of the organization, number of incoming requirements and RE experience of respondents, it was found that the respondents with less RE experience for handling large number of incoming requirements and from large organizations handling less number of incoming

## Table 3: Percentage of responses for dependencies considered today and to be considered ideally

<table>
<thead>
<tr>
<th>ID</th>
<th>Dependencies</th>
<th>Today</th>
<th>Ideally</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>C-VALUE</td>
<td>16%</td>
<td>14%</td>
</tr>
<tr>
<td>D2</td>
<td>AND</td>
<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>D3</td>
<td>OR</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>D4</td>
<td>REQUIRE</td>
<td>13%</td>
<td>14%</td>
</tr>
<tr>
<td>D5</td>
<td>TEMPORAL</td>
<td>13%</td>
<td>12%</td>
</tr>
<tr>
<td>D6</td>
<td>I-COST</td>
<td>12%</td>
<td>15%</td>
</tr>
</tbody>
</table>

An overall summary of criteria considered today and to be considered ideally with respect to different perspectives is available online [30]. The responses for consideration of criteria today and ideally differ very slightly (mostly by 1%). This means that respondents are satisfied with the criteria they use today and do not want to change the criteria significantly. However, it is surprising if criteria T7, T8, T9, T10 and T12 which are related to the long-term business goals, are considered during triage, respondents still feel that C1, i.e. difficulty in aligning requirements with long-term business goals, is the most applicable challenge. This discrepancy needs detailed exploration and thorough investigation.

From the responses in the survey (see online [30]), it was found that there are no fundamental differences with respect to the size of organizations, number of incoming requirements and RE experience of respondents on the criteria used today and should be used ideally. This was further confirmed by the t-test of independent samples.

Only respondents, who have less RE experience and work in large scale organizations with lower number of incoming requirements, responded that they do not use any explicit criteria today but would ideally like to use all the 12 criteria mentioned. It is good, on one hand, to evaluate requirements in detail, however, this raises questions about the time and resources needed to do such an extensive evaluation.
requirements stated no dependencies are considered while taking triage decisions. Maximum number of dependencies is reported to be considered by large organizations handling less than 50 requirements per month. Whereas, respondents belonging to small organizations handling large number of incoming requirements and having a lot of RE experience reported to consider only one dependency i.e. D1: C-VALUE.

For an ideal scenario, almost all the respondents stated they would like to consider all dependencies except respondents belonging to small-scale organization handling large number of incoming requirements with less RE experience (who want to consider no dependencies) and respondents belonging to large organization handling less than 50 requirements per month and having high RE experience (who want only D6 to be considered ideally during triage).

From t-tests it is found that the size of the organization and RE experience of respondents have no affect on the consideration of dependencies today and ideal. However, the number of incoming requirements does have an effect on the consideration of D5 today. But the reasons for this were not elicited in the survey and need to be investigated in future.

**Storing Decision Attributes for learning**

There are four different types of requirements triage decision attributes (identified through SLR) that can be stored by the organizations, presented in Table 4. Analysis of results reveals that more respondents would ideally want to store A1 (decision rationale) and A4 (interdependencies).

<table>
<thead>
<tr>
<th>ID</th>
<th>Decision attributes</th>
<th>Today</th>
<th>Ideally</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Decision-rationale</td>
<td>19%</td>
<td>24%</td>
</tr>
<tr>
<td>A2</td>
<td>Requirements triage criteria</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>A3</td>
<td>Cost-estimations</td>
<td>22%</td>
<td>21%</td>
</tr>
<tr>
<td>A4</td>
<td>Interdependencies</td>
<td>21%</td>
<td>22%</td>
</tr>
</tbody>
</table>

An analysis of the categorization of decision attributes with respect to the size of the organization, number of incoming requirements and RE experience of revealed that small-scale organizations handling less number of requirements with less experience are storing only A3 today, while they would like to ideally store A1 and A4. Large-scale organizations are storing A2, A3, A4 today, while in contrast they want to store A1 attribute only ideally. From the collected data, it is found that large-scale organizations are either not storing decision attributes or would want to reduce the number of decision attributes. Moreover, respondents with high RE experience working in small organizations with large number of requirements responded that no decision attributes are stored today and they would not want to store any decision attribute in an ideal scenario. These are interesting findings but the reasons for these results need to be explored. Statistically, we are unable to find the effect of size of the company, number of incoming requirements and RE experience of respondents on the decision attributes stored today and that should be stored ideally.

**VII. SUMMARY AND DISCUSSION**

This paper presents state-of-the-art and state-of-practice for requirements triage and selection. For the SLR, 23 studies were selected that either proposed new solutions for requirements triage and selection or reports of experiences in using such solutions.

Requirements triage and selection is one of the initial activities in MDRE. The cost and effort for rectifying the mistake of selecting a wrong set of requirements at later stages of requirements engineering process is huge [34] and sometimes irreversible. The chances of selecting a wrong set of requirements during triage and selection are greatly increased if the above mentioned challenges (Section Error! Reference source not found.) are not handled. This calls for a requirements triage and selection solution that handles all or most of the above mentioned challenges, however, none of the solutions handle all the identified challenges.

In order to identify the most applicable challenges in industry and how they are handled today and should be handled, a survey was designed. The results of the survey showed that although all four challenges (C1-C4) are faced by the respondents, C1 (Difficulty in aligning requirements with long-term business goals) and C2 (Requirements dependencies) being the most applicable challenges in the industrial context. In relation to this, it is surprising that requirements triage criteria T7, T8, T9, T10 and T12 which are related to the long-term business goals, are currently considered during triage; respondents still feel that C1 is the most applicable challenge. Whereas, the literature proposes use of this criteria for aligning requirements with long-term business goals. Moreover, although almost all the respondents reported to consider the requirements dependencies, still the industry is faced with the challenge of handling requirements dependencies. Such discrepancies need detailed exploration and thorough investigation.

Although almost all the proposed requirements triage and selection solutions claim to handle atleast one of the four challenges (C1-C4), these challenges still prevail in industry. Especially C4 is the third most applicable challenge during requirements triage and none of the existing proposed requirements triage and selection solutions address this challenge.

From the results of the survey, it could not be identified if size of the organization, number of incoming requirements and RE experience of individuals effect the applicability of the challenges and factors considered addressing them.

There may be several explanations for the results of the industrial survey. The challenges still prevail in the industry may be because that the usability and usefulness of the proposed solutions are not demonstrated sufficiently (a finding from the SLR) making it difficult for industry practitioners to adopt a triage and selection solution. Practitioners would probably not take the risk of implementing a solution, as it falls short on reporting even rudimentary evidence on efficiency. It could also be the case that industry practitioners are not aware of the current research literature. Moreover, it is surprising to find that size of the organization, number of incoming requirements and RE experience of respondents does not affect the applicability of the challenges. It has been assumed in literature that organizations with large number of incoming requirements face challenges related to triage [2], however, according to the survey findings the challenges are same for organizations handling less number of requirements per month.
From the review perspective, a potential conclusion validity threat is the reliability of the data extraction categories. To minimize this threat, GQM was used in several brainstorming sessions to extract the research questions and based on the research questions, measures (in this case the data extraction categories) were identified from peer-reviewed publications [15, 30, 32] (see Section Error! Reference source not found.). In addition, the results presented in the review are not categorical. Any evidence, or claim made by authors are given the benefit of the doubt and counted as evidence. However, the claims are broken down and analyzed, and the value can be judged by the reader as every analysis and analysis step is transparently available online [30].

It is quite possible that the studies included in the review might not refer to the same construct using same terms thus as reviewers we might misinterpret the terms used. However, we feel fairly confident that the risk is rather minor as in addition to the term there is a context in which the term is used which minimizes the chance of misinterpretation.

There are certain limitations of the survey results as well. First of all the number of responses is 33. If it had been more, external generalizability would have increased, however, the respondents are involved in requirements engineering in general and requirements triage and selection in particular which ensures that relevant responses for the survey were gathered (highly experienced requirements managers were among the respondents). The survey can be replicated with a larger population of respondents to confirm/contradict the findings. Through survey, it was not possible to investigate in detail the conflicting results; however, this forms a basis for our future work.

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