What Stakeholders Need to Know about Requirements

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Abstract—Working with requirements is a knowledge-intensive task. Stakeholders need various information, e.g., for understanding or negotiating the requirements. To understand the information needs of stakeholders we conducted two case studies and interviewed 6 stakeholders. We identified 26 unique information needs, which we represented as questions asked by stakeholders such as "Are there redundant requirements?" or "How did other stakeholders prioritize the requirements". We grouped the needs into five situations in which they were encountered. These were defining, understanding, evaluating, negotiating, and planning requirements. We then surveyed 307 practitioners to quantify the frequencies of these needs and assess how well current tools satisfy them. About 60% of the respondents confirmed that they frequently encounter the needs while their tool support was poor or absent. Requirements engineers and experienced stakeholders were particularly unsatisfied with their tools. The largest gap between the importance of the information and the degree of tool support could be detected for information about the opinions of other stakeholders and conflicting preferences while understanding and negotiating requirements.

I. INTRODUCTION

Stakeholders are people with specific interests in system requirements and the outcomes of development projects. They can be e.g., customers, requirements engineers, analysts, domain experts, or developers. Typical tasks which involve stakeholders are the definition, negotiation, or planning of requirements. When working on these tasks, stakeholders encounter questions and need to obtain specific information about requirements. For example, during requirements definition stakeholders might seek information about similar or related requirements. During requirements negotiation, stakeholders might seek information about the feasibility or the implementation costs of requirements. Answering questions of stakeholders is crucial for the successful completion of these tasks and might take time and effort.

Requirements engineering (RE) tools can play an important role in answering stakeholders questions and satisfying their information needs [4]. For effective tool support, we must first understand what information stakeholders need when working with requirements and how well the current tools help in accessing this information. To this end, we conducted a multi-annual, multi-organizational empirical study. We first conducted two case studies and interviewed six practitioners to identify which questions stakeholders ask, when, and why. We identified 37 questions stakeholders ask in five situations. Then, we surveyed 307 practitioners about the frequency of these questions and how well current tools support them to

answer the questions. Our results reveal a gap between sought and provided information in current RE tools. In particular, tools lack the assistance to cope with enormous information overload, the continuously evolving requirements, and the changing preferences of other stakeholders.

The contribution of this paper is twofold. First, it identifies types of information needed when working with requirements and represents the needs as stakeholder questions. Second, the paper quantifies the frequency of these needs, how well current RE tools supply them, as well as correlations between the needs and specific groups of stakeholders.

The remainder of the paper is organized as follows. Section II introduces the research questions, method, and data. Section III summarizes the qualitative findings from the case studies in form of information needs. Section IV reports on the quantitative findings, including the frequencies of information needs and assessment of current tool support. Section V discusses the threats to validity. Finally, Section VI highlights related work, while Section VII summarizes the paper.

II. RESEARCH SETTING

The goal of this research is to identify the information needs of stakeholders when working on requirements engineering tasks. We wanted to assess which information is important and to which extent it is provided by current tools in practice. We focus on the following specific questions:

1) What information do stakeholders need to know while performing RE related tasks?
2) How well do current tools satisfy stakeholders' information needs?

Our method for answering these questions consisted of a qualitative and a quantitative phase. The first phase aimed at developing an in-depth understanding of RE information needs. In this phase, we conducted two case studies interviewing 6 practitioners. The second phase aimed at validating and quantifying the needs while assessing current tool support. In this phase, we conduced an online survey with a broad sample.

A. Qualitative Phase: Case Studies with Interviews

To answer the first research question, we conducted two case studies between July and October 2010 in two companies COMP1 and COMP2. We selected the cases during a consortium building activity for a collaborative research project within the EU Framework Programme 7. The first case

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represented large open source projects while the second case represented commercial multi-organization projects.

COMP1 was a software tool vendor and a key player in two large open source communities REV and Eclipse. REV includes more than 750 projects that focus on collaboration and revision control systems. Eclipse comprises a multi-language integrated development environment and a Rich Client Platform. The case was OPENP, a project that integrates REV into Eclipse. OPENP had about a half million users who generated between 2009 and 2010 over 7000 requirements. Every OPENP user can submit change requests and propose features via the project issue tracker. OPENP had worldwide about 50 active project leads, analysts, architects, and developers. Decisions about the requirements required an intensive communication with numerous of clarification requests and negotiation rounds. COMP1 spent yearly several hundred thousands of Euros to coordinate this effort. The largest part of the cost was needed for managing the requirements and the stakeholders. In addition, the project had severe interdependencies the with Eclipse and REV communities. Any evolution in these platforms must be reflected in OPENP. Every hour change requests had to be examined and eventually forwarded to the Eclipse or the REV community.

COMP2 was active in the aerospace and defense domain, where requirements have a fundamental importance and must be clearly defined, complete, coherent, implementable, traceable, and verifiable. COMP2's projects typically take several years and involve globally distributed teams. The case was a development project for a flight control system, where COMP2 personnel defined requirements together with customer representatives. These were different people with different priorities and knowledge. The project included about 20 subsystems (which are themselves considered medium to large sub-projects). Distributed expert teams including program and project managers, reliability, mechanic, aerodynamic, computer experts, domain experts (i.e., navigation) were involved. Each team has a particular background, preferences, and a vision of the system, which make information sharing and understanding of individual preferences difficult.

The first research question was sent to representatives of COMP1 and COMP2. They suggested the cases from their organizations and sent details as well as additional materials and documents describing typical tasks from the cases. We then interviewed three representatives for each case study via phone and sent clarification questions afterwards via emails. Each interview lasted for 30-60 minutes. The summary of the identified information needs were sent to the case representatives for reviews. Section III reports on the results.

B. Quantitative Phase: Online Survey

We designed an online survey which consisted of two parts. The first and main part aimed at validating the identified information needs and quantifying their frequencies while assessing the current tool support for supporting these needs. In the second part we aimed at collecting respondents demographics. We asked about projects characteristics such as project size and distribution as well as personal information such as working experience and project roles. Overall, the survey included 18 questions with fixed choice items which took about 15 minutes to answer. Respondents were also able to propose additional needs and comments in terms of free text answers.

For the closed questions, we used a semantic scale [7] to assess frequencies of information needs and the satisfaction with the tool support for meeting the needs. For assessing the frequency of how often the information needs were encountered, respondents could choose between *Never* (-2), *Rarely* (-1), *Sometimes* (0), *Often* (1) and *Usually* (2). For assessing the tool support the options were *Absent* (-2), *Poor* (-1), *OK* (0), *Good* (1) and *Excellent* (2). The numbers in parenthesis are numerical representations of the items used for the data analysis. The survey was available in English and German. The survey forms and the anonymized raw answers can be downloaded from http://mobis.informatik.uni-hamburg. de/2014InfoNeedsRE/.

To participate in the survey people should have experience with requirements engineering. We recruited the respondents through 15 channels. We advertised our survey in online communities, mailing lists, forums (e.g., REOnline), news sites, and social networks (LinkedIn groups and twitter). We circulated the survey across companies in Europe and Asia, with which we are collaborating. We also asked two vendors of RE tools (Polarion Requirements and Doors) to publicize the survey in their newsletters. As an incentive, we raffled one iPod among respondents who completed the survey.

In total we received 475 responses between September 2011 and February 2014, of which we identified 307 as valid, i.e., responses in which at least half of the questions were answered. In 262 responses all questions were answered.

The respondents came from industry and were rather experienced. About half of the respondents (45%) have more than 10 years of work experience, 26% had 6-10 years, while 22%) had 3-5 years of work experience (see Fig. 1a). About half of respondents had worked as requirements engineers or analysts, followed by managers (40%), and developers or architects. About 20% of respondents worked as testers. 74% of respondents mostly work in closed source projects, 7% worked in open source projects, while remaining 19% worked on both (see Fig. 1b). About 46% of respondents followed a heavy-weight development process such as V-Model and 43% followed an agile process such as Scrum. More than half of the respondents (62%) collaborated with 1-25 people (including customers, suppliers, and team members) in a typical project, while about 18% collaborate with more than 50 people. The remaining 20% collaborated with 26-50 people (see Fig. 1c).

We also asked respondents which RE tool they were using and gave the following options: requirements management tool (such as Doors or Polarion Requirements), Office tools, Wikis, issue trackers (such as Bugzilla or Jira), no tool, or other tools. Multiple selections were allowed. About half of the respondents used Office, Wikis, and Issue trackers. 40% of respondents stated to use RE tools as Doors, while only 4% expressed they don't use any RE tool. Five respondents stated

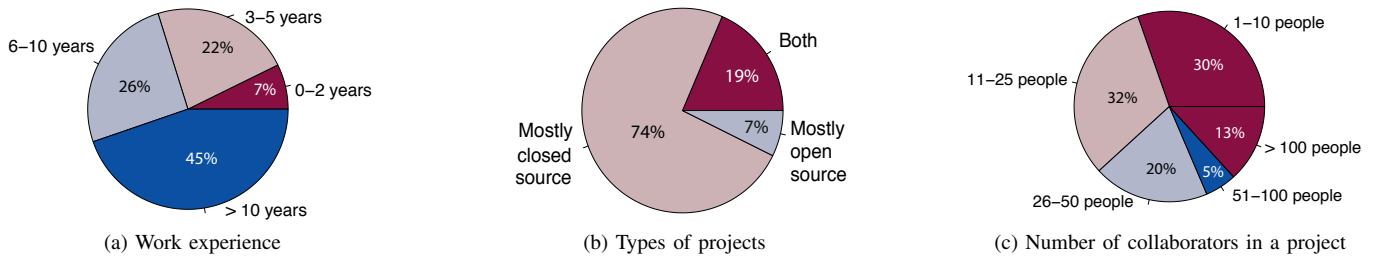(a) Work experience   (b) Types of projects   (c) Number of collaborators in a project

Fig. 1: Demographics of respondents in the online survey. N=307

the use of an own developed tool. Team Foundation Server and Sharepoint were reported by three respondents each.

Data analysis: We ran within-questions and between-questions analyses. Within-questions analysis confirmed whether the proportions of respondents having opposing opinions for a single question is significant, e.g., whether the ratios of respondents that have a frequent need and those that do not are statistically significant. Between-questions analysis allowed us to identify and confirm trends and correlations between the answers of different groups of respondents.

We applied the Mann-Whitney-Wilcoxon test (also known as Wilcoxon rank sum test) to verify whether the difference of two responses is statistically significant. This allowed us to verify the significance of differences between information needs and tool support, or between demographic factors such as role or experience. Wilcoxon test is considered appropriate for ordered semantic scales and subsamples of different sizes [1]. We correlated the answers of respondents to identify particular trends amongst them using the Kendell's τ rank correlation coefficient. We report only on statistically significant results using a significance level of 0.05 as a threshold.

III. QUALITATIVE RESULTS: INFORMATION NEEDS

From the data collected in the case studies and the interviews we derived 26 information needs which we formulated as questions. We grouped the needs into the situations (i.e., types of tasks) in which they typically arose. Overall, participants reported the following five situations: defining requirements, understanding requirements, evaluating requirements, negotiating requirements, and planning requirements. We describe the situations and information needs identified.

A. Defining Requirements

Table I shows the identified information needs which are encountered by the case studies participants when defining new requirements. Participants stressed the need to know redundant and related requirements mainly with the objective of reuse and to "shorten the requirements phase and reduce the costs" as one participant from COMP2 claimed. Participants mentioned the interest in different types of relationships such as "refines", "is a part of", "depends on", and "incompatible with".

Participants from both case studies also sought keywords to annotate the requirements. Thereby they aimed at classifying and clustering the requirements, e.g., by topics, components, or

Table I: Stakeholders questions when **defining** requirements.

Info need	Question
Redundant req.	Are there other redundant requirements?
Related req.	Are there related requirements, which I should know?
Keywords	Which keywords should annotate this requirement?
Vocabulary	Which vocabulary/terms should be used?
Templates	Am I using the right templates?
Contact person	With whom I should discuss the new requirement?
Quality est.	How do other stakeholders assess the requirement quality?
Feasibility est.	How do other stakeholders estimate the requirement feasibility?

Table II: Stakeholders questions when **understanding** requirements.

Info need	Question
Author intention	What was the stakeholder's intention when defining this requirement?
Related req.	What are related requirements?
Related artif.	Which related artifacts do I need to look at?
Keywords	To which keywords does this requirement belong?
Proposer	Who proposed this requirement?
Contact person	With whom can I discuss this requirement?
Feasibility est.	How do other stakeholders estimate the requirement feasibility?
Quality est.	How do other stakeholders assess the requirement quality?
Importance	How important is this requirement for particular stakeholders?

type of requirements. For example COMP1 participants used keywords related to the open source communities Eclipse and REV, while COMP2 used the name of mechanical components as keywords. Participants also sought information on vocabulary to increase consistency and avoid misleading terms (i.e., how do other stakeholders call this concept).

Interestingly, participants mentioned also the need for *information about people*, mainly to know the right stakeholders to discuss a requirement or to get feedback about the quality and feasibility of the requirements they are defining.

B. Understanding Requirements

With understanding requirements participants meant reading requirements with the objective of using them for a particular task (e.g., implementation, testing, or project management). Participants had eight major questions when understanding a requirement as shown in Table II.

Participants stated that a related artifact can be any document with additional information which helps to understand and use the requirements such as an email, a model, a piece of code, a legal paragraph, or a document from the domain. The stakeholder who proposed the requirement as well as her intention and goal, i.e., the reason for the requirement, was mentioned in both cases as needed information.

Table III: Stakeholders questions when **evaluating** requirements.

Info need	Question
Related req.	What are related requirements?
Related artifacts	Which related artifacts do I need to look at?
Keywords	To which keywords does this requirement belong?
Similar eval.	How were similar requirements evaluated?
Maintainer	Who is responsible for maintaining the requirement?
Proposer	Who proposed this requirement?
Stakeholder eval.	How did stakeholders evaluate this requirement?
Team eval.	How did my team members evaluate this requirement?

Participants also stated that they need to know the *assessment of others* as this information helps them understanding requirements and "putting them in the real word context" as one participant from COMP2 stated.

C. Evaluating Requirements

With evaluating requirements participants meant reasoning about the requirements and assessing their properties such as quality or feasibility. One participant from COMP1 stated: "we evaluate the requirements mainly to increase their quality and reduce redundancy. The objective is to reduce the number of bugs and build failures caused by incompatible requirements (e.g., inter-dependencies within OPENP and with the new versions of Eclipse and REV).

Participants from COMP2 agreed that the requirements phase should produce a *common* but very qualitative view on what the product shall be. One participant from COMP2 claimed: "Requirements management tools which we use are *passive*. They provide support for writing, cataloging, and updating the requirements. What is needed, however, are pro-active tools that drive us, suggesting what is missing or mandatory required for the domain, and help us to achieve completeness, detect lacks, and pitfalls".

We identified eight major questions asked when evaluating a requirement as shown on Table III. The needs were similar to those identified for defining and understanding requirements, including related requirements, related artifacts, keywords, and responsible stakeholders. Participants also claimed the need to know the evaluation of others, including team members and other stakeholders. Participants from COMP2 argued that this information "helps to optimize and shorten approval processes and reduce communication overhead around requirements". COMP1 participants argued that other stakeholders have experience and knowledge about the project or the domain, which can save evaluation effort if shared with them.

D. Negotiating Requirements

Requirements negotiation and prioritization tasks were knowledge-intensive in the studied cases. Participants reported seven questions they ask during these tasks as shown on Table IV. Most importantly, participants stated questions about the preferences of others as well as alternatives in case of conflicts. The reason for this information need was twofold. First, participants claimed that knowing this information will make the selection and prioritization for requests and suggestions about requirements more efficient as conflicts can be avoided before they emerge or hidden conflicts will become explicit

Table IV: Stakeholders questions when **negotiating** requirements.

Info need	Question
Stakeholder prio.	How did other stakeholders prioritize these requirements?
Team prior.	How did my team members prioritize these requirements?
Conflicts w. stakeholders	Is my prioritization contradicting other stakeholders' prioritization?
Conflicts w. team	Is my prioritization contradicting a team member's prioritization?
Prio. feasibility	How realistic is my own prioritization in terms of needed resources?
Contact person	With whom should I discuss these requirements?
Acceptable alternatives	How can I make my prioritization consistent with the prioritization of other stakeholders?

Table V: Stakeholders questions when **planning** requirements.

Info need	Question
Alternative plans	What are reasonable alternative plans?
Stakeholder assessment	How did other stakeholders assess these alternatives?
Team assessment	How did my team members assess these alternatives?
Acceptable alternatives	Which alternatives are similar to my preference and consistent with other's preferences?
Contact person	With whom should I discuss these alternatives?

quickly. Second, participants argued that information about the preferences helps them to assess future changes.

E. Planning Requirements

The last situation, which was covered in our case studies is planning requirements into releases. We identified five questions participants encounter during this situation as shown on Table V. Participants from COMP1 and COMP2 argued that this information is needed mainly for the efficient allocation of resources and people as well as for "Higher transparency of decision processes related to requirements selection and release planning" as one participant from COMP1 stated.

Participants mentioned the need to know alternative plans, which are "reasonable". Again in this situation, the preferences and opinions of other stakeholders were reported as needed information. Moreover, participants stressed the need to know conflicting preferences and alternative solutions. One participant from COMP2 stated: "one key aspect for all stakeholders in our project is to deliver cost effective and *commonly agreed requirements*". Therefore, information about the assessments of others and matchmaking of the opinions was important.

IV. QUANTIFYING INFO NEEDS AND TOOL SUPPORT

The trend in the responses was consistent as shown on Fig. 2. Overall, a majority of participants (59%) confirmed the identified information needs, indicating that they encounter them often of usually. A majority (58%) also state that their tool support for the needs falls short of expectation (i.e., poor or absent), indicating a *gap* between the information needs and the tool support. We define this gap as the difference (absolute value) between the positive and negative assessment ratios.

To check the reliability of the results, we calculated Cronbach's α. This measure assesses the internal consistency of the survey variables and is recommended for semantic scales [6], [9]. Cronbach's α was high for all questions which address the information needs and tool support ($0.90 < \alpha < 0.96$).
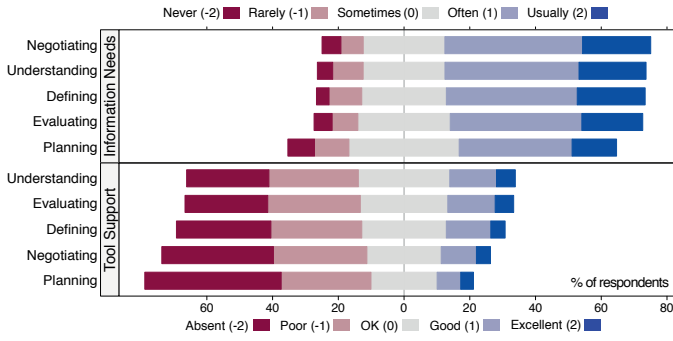
Fig. 2: Summary of respondents' assessments for information needs and tool support ordered by the ratios of positive assessments.

When defining requirements, 61% of respondents stated to encounter the identified questions often or usually (i.e., high need), compared to 14% of respondents who never or rarely encounter the questions. In contrast, 56% of the respondents negatively assessed the tool support (i.e., poor or missing support) for the needs identified, while a fraction of 18% states the opposite (i.e., good or excellent support). This gap was consistent for all studied working situations. For understanding requirements 61% of the respondents claimed a high need (opposed to 14% who had a low need) while 52% claimed a bad tool support (as opposed to 20% how were satisfied). For evaluating requirements, 59% frequently encountered the needs (13% stated the opposite), while 53% had a poor tool support (20% stated the opposite). The biggest gap was for information related to negotiation requirements. While 62% of the respondents expressed a high need for this information, the same fraction rated the tool support as poor or absent. Finally, 48% rated the information needs related to requirements planning as high, 35% were neutral (i.e., sometimes), while 17% estimated the needs as low. In contrast, a large majority (69%) stated that their tool support for accessing the information was poor and 20% were neutral. We discuss the results for the information needs, the tool support, and the differential analysis.

A. Information Needs

1) Defining Requirements: The top part of Fig. 3 summarizes the frequency of stakeholder questions encountered when defining requirements. Questions about related requirements seem to be the most frequently encountered. A majority (55%) confirmed the importance of this information, while only 12% expressed low or no need for it. Least needed information seems to be information about the right templates. 50% of the stakeholders rated this information need as high, in contrast to a fraction of 25% who stated the opposite.

We observed several significant differences between respondents with different roles ($p < 0.04$, pairwise Wilcoxon tests). Requirements engineers were more interested in related requirements than testers. Managers needed to know information about redundant requirements more frequently than developers and testers. Managers also expressed a higher need for information on related requirements than testers and of information
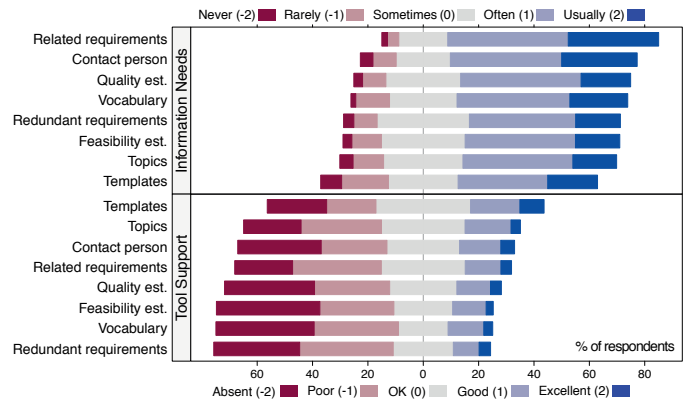

Fig. 3: Frequency of ratings on information needs and tool support when **defining requirements** (see Table I)
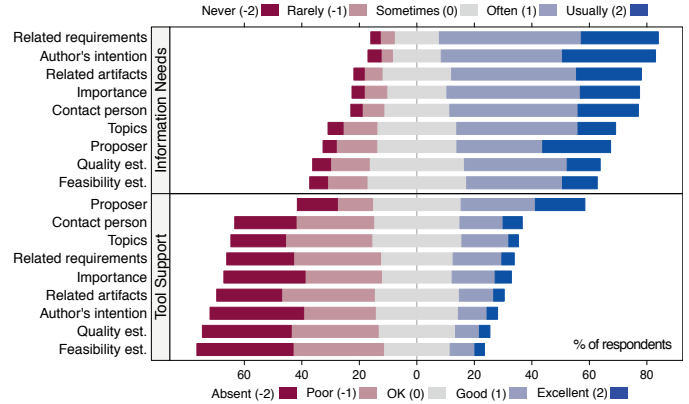

Fig. 4: Frequency of ratings on information needs and tool support when **understanding requirements** (see Table II)

on templates than developers. Architects more frequently have to answer questions regarding the right templates than testers.

Stakeholders who were mainly involved in face to face collaborations claimed a less frequent need for information on requirement feasibility than those who mainly use other interaction styles such as phones ($p < 0.03$, Wilcoxon pairwise tests). Furthermore, stakeholders working mostly in open source projects expressed less needs for information on vocabulary than those working mostly in closed source projects ($p < 0.038$, Wilcoxon test). Finally, we also identified a correlation between the need for information about people and the experience of the respondents. The need to know the right stakeholders to discuss the requirements tends to decrease with experience (p < 0.008, Kendell's $\tau \approx -0.13$).

2) Understanding Requirements: The top part of Fig. 4 shows the frequency distributions of the information needs of respondents when understanding requirements. Again, related requirements were ranked as highest need in this situation. This was supported by 76% of the respondents, as opposed to 8% who rated this information to be needed rarely or never. The least needed information was about requirement feasibility. Only 45% of respondents rated it as high, while a fraction of 20% stated the opposite.

Participants working in open source projects expressed less information needs than participants working in closed source
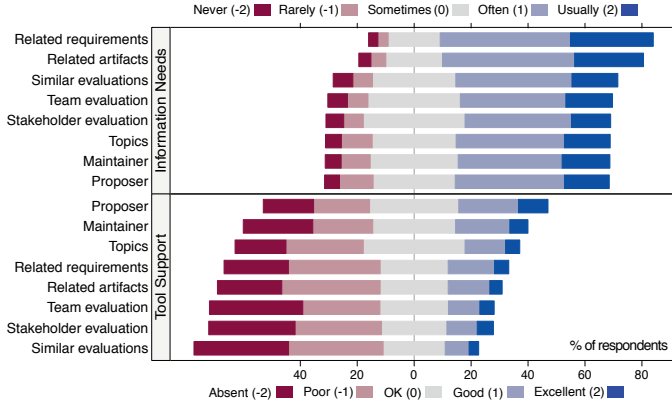
Fig. 5: Frequency of ratings on information needs and tool support when **evaluating requirements** (see Table III)

projects. In particular, they reported less need for information on (a) right stakeholders to discuss a requirement, (b) the intention of authors, (c) the right vocabulary, (d) and the opinions of other stakeholders on the importance and the quality of a requirement ($p < 0.038$, pairwise Wilcoxon tests).

Finally, the more experienced the stakeholders are, the more they seem to be interested in the intention of authors when understanding requirements ($p < 0.0003$, Kendell's $\tau \approx 0.18$).

3) Evaluating Requirements: The top part of Fig. 5 shows the respondents ratings for the information needs regarding the evaluation of requirements. In this situation, related requirements were also rated as most frequently needed information. 75% of the respondents rated this need as high, while only 7% stated the opposite. Information about the author was rated as least needed. 52% of respondents expressed a high information need, compared to 12% who stated the opposite.

When cross-tabulating the responses, we found that managers and architects expressed a higher need than testers for information about related requirements ($p < 0.01$, Wilcox test). Respondents who mainly collaborated face-to-face had a higher need for related artifacts than those with distributed collaborators ($p < 0.05$, Wilcox test). Finally, the more experienced respondents were, the more frequently they needed to know related requirements ($p < 001$, Kendell's $\tau \approx 0.18$).

4) Negotiating Requirements: The top part of the Fig. 6 shows the frequencies for information needs when negotiating requirements. The most popular need was on how realistic a requirement is. This was confirmed by 73% of the respondents, while only 8% have expressed low or no need for this information. The least popular information was on the awareness about conflicts with *the team*, which was rated as high by 54% of the stakeholders and as low by 15% of them.

Having a closed look at the data, we found that respondents who have mainly face to face meetings expressed less needs for knowing (a) the right stakeholder for discussion and (b) prioritization of other stakeholders, than those who mainly use other interaction styles ($p < 0.03$, Wilcoxon tests).

5) Planning Requirements: The top part of the Fig. 7 shows of the respondents ratings for the information needs regarding requirements planning. Overall the ratings were similarly dis-
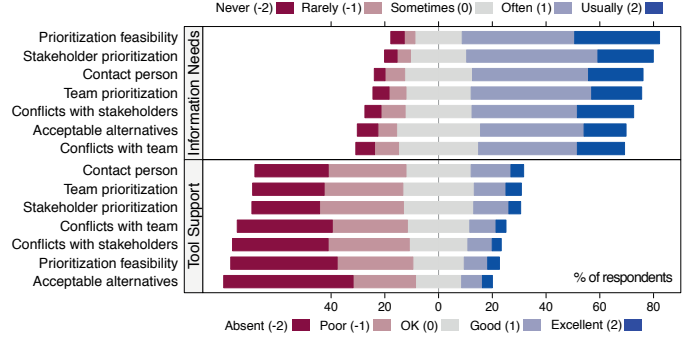

Fig. 6: Frequency of ratings on information needs and tool support when **negotiating requirements** (see Table IV)
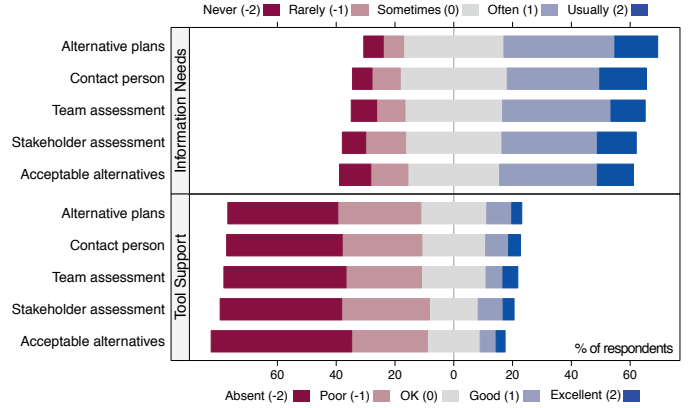

Fig. 7: Frequency of ratings on information needs and tool support when **planning requirements** (see Table V)

tributed for the various information needs. The most popular information need according to 52% of the respondents was about alternative plans for the requirements. A fraction of 13% expressed low or no need for this information. The question "which alternatives are similar to my preferences and consistent with others' preferences" was rated as least frequently encountered. 47% of the respondents rated this need as high, while 23% claimed the opposite.

A differential analysis showed again that respondents who mainly interact in a face to face manner with the other stakeholders were less interested to know about the stakeholders assessments of the alternatives, than those who mainly use other interaction styles ($p < 0.05$, Wilcoxon tests).

B. Tool Support

1) Defining Requirements: The bottom part of Fig. 3 gives an overview of the frequency distribution of answers on tool support when defining requirements. The tool support for answering questions about templates ranked best and was rated by 26% of respondents as positive, while the majority (40%) still consider it as low or not available. Tool support for dealing with redundant requirements seems to be the worst. Only 13% of the respondents expressed their satisfaction with current tool support, while a majority (65%) stated a low or no-existent tool support. The biggest gap between the information need and its tool support was on related requirements and the smallest gap on templates ($p < 2.41e - 09$, Wilcox tests).

Developers were more satisfied with the tool support regarding information about vocabulary, quality, and feasibility of a requirement than managers. Users of requirements management tools seem to have better tool support on accessing information about topics, templates, and related requirements than users of Wikis, issue trackers, and Office tools ($p < 0.048$, pairwise Wilcox tests).

2) Understanding Requirements: The bottom part of Fig. 4 gives an overview of the assessments for the tool support when understanding requirements. The support for information about the author seems to be the best. 43% rated it as high, while a fraction of 26% respondents rated it as low. Tool support for information on requirement's feasibility seems to be the worst. Only 12% were satisfied with the tool support for this information, while the majority (64%) stated the opposite. The biggest gap between information need and tool support was on author's intention, while the least gap was on the feasibility of a requirement ($p < 1.41e - 32$, Wilcoxon tests).

When cross-tabulating the answers, we found that managers were less satisfied than developers with their tool support to supply their information needs for understanding requirements ($p < 0.05$, Wilcoxon pairwise tests). Users of requirements management tools such as Doors were more satisfied with the support to access information about (a) the author of a requirement and (b) author's intentions than users of Wikis, office tools, and issue trackers ($p < 0.034$, Wilcox's tests).

The satisfaction with the tool support for most information needs decreases when the experience of respondents increases ($p < 0.03$, Kendell's $\tau \approx -0.13$ for 5 out of 9 needs).

3) Evaluating Requirements: The bottom part of Fig. 5 gives an overview of the assessments for the tool support when evaluating requirements. According to 37% of the respondents, the best tool support is available for information about the owner of the requirement, while 31% stated the opposite. The lowest tool support seems to be for getting information about similar requirements. Only 12% rated the tool support as high, while 66% stated the opposite. For this information need, requirements engineers were the least satisfied with the tool support than other roles. The biggest gap was on related requirements, while the lowest was on accessing stakeholders' evaluations ($p < 2.16e - 31$, Wilcox tests).

In addition, we found that the more experienced respondents were, the less satisfied they were with their tools to access information on team's evaluation and stakeholders' evaluation ($p < 0.001$, Kendell's $\tau \approx 0.16$). Users of RE tools such as Doors, RequisitePro, and Polarion Requirements seem to be more satisfied with their tool support for finding related artifacts than Office users ($p < 0.048$, Wilcox test).

4) Negotiation Requirements: The bottom part of Fig. 6 shows the summary of the ratings for tool support when negotiating requirements. According to 19% of the stakeholders, the best tool support seems to be for finding of relevant stakeholders for discussion, while the majority (56%) expressed low or no need. The least tool support seems to be available for looking up of reasonable alternatives. Only 11% were satisfied. A major fraction of 71% stated that the current

tool support is low or not available. The biggest difference between information need and tool support when negotiating requirements was on the feasibility of the prioritization, while the lowest gap was on potential conflicts with team ($p < 1.71e - 42$, Wilcoxon tests). The satisfaction with the tool support for reasonable alternatives seems to decrease with experience as well ($p < 0.0001$, Kendell's $\tau \approx -0.20$).

5) Planning Requirements: The bottom part of Fig. 7 gives an overview of the frequency distribution of the answers for the tool support when planning requirements. Information about alternative plans is rated to be well accessible by 12% of the respondents, while 66% expressed a low or non existent support. Only 8% of the respondents rated their tool support to access information about acceptable alternative plans as positive, while the majority (73%) rated it as poor or completely absent. The biggest difference between information need and tool support was on reasonable alternatives. The lowest gap was on acceptable alternatives ($p < 1.23e - 37$, Wilcox tests).

Managers, requirements engineers, and architects where less satisfied with their tools to find the right stakeholder for discussion than developers. They were also less satisfied than testers on finding acceptable alternatives ($p < 0.04$, Wilcoxon pairwise tests). Finally, the satisfaction with the tools to find the right stakeholders for discussion seems also to decrease with experience during requirements planning ($p < 0.001$, Kendell's $\tau \approx -0.22$).

V. Threats to Validity

There are several limitations to the internal and external validity of our results. The goal of this study was to identify questions stakeholders ask when working with requirements and assess the quality of the tool support to answer them. The reported questions were derived from a careful qualitative investigation in two different case studies with six interviews. To reduce observer bias, the collected data was peer-analyzed and the results sent to the interviewees, who have confirmed them. The identified questions were then validated by a broad number of heterogeneous stakeholders from industry in the survey. However, the set of stakeholders questions identified in this study is not meant to be *complete*, as we might have missed other important questions. For a complete set, our study should be replicated by other researchers in different settings. There are also other types of requirements tasks such as requirements validation, which we did not study and which might lead to additional questions. Other empirical methods such as field observation of stakeholders or content analysis might also reveal additional questions.

As for any survey, the selection of the questions and answer options always represent a potential threat. All our survey questions were derived from the qualitative phase. As we had to limit the number of questions, might thereby have influenced the respondents. To decrease this threat we carefully designed our survey in an iterative manner and discussions with experienced researchers and experts from industry. We ran serval pilot tests with colleagues and refined the survey

based on the feedback. We filtered and improved some questions to make the survey answerable in 10-15 minutes. Further, we tested the visual appearance of the survey on different browsers and platforms to ensure a high usability. We also allowed respondents to suggest additional information needs and comments by entering a free text.

As for the generalizability of the quantitative results, we do and can not claim generalization of all findings as we did not use representative sampling. Such a sample could only be derived with random selection and stratification, if and only if, the whole population of stakeholders is known. This could be e.g., achieved by replicating the study for a specific organization. However, by collecting 307 valid answers of diverse stakeholders from 15 different channels, we think that the observed trends, frequencies of the information needs and assessment of tool support have an acceptable level of external validity. We only report on statistically significant results verified by statistical tests to exclude observation by chance [7]. Therefore, we feel confident about the validity of the result concerning the differential analysis and the gaps between information needs and tool support.

VI. RELATED WORK

In last years several authors studied information needs in software engineering, focusing on the developers perspectives during bug fixing, program comprehension, or evolution tasks. Ko et al. [3] studied information needs of developers in collocated teams, in which they observed 17 developers at Microsoft. Similarly, Sillito et al. [8] observed 25 developers and identified 44 questions specific to software evolution tasks. The authors also identified problems around answering these questions such as "the information scatter across the tools" or "a missing tool support for asking more refined or precise questions". As in our study, these observational studies also formulated information needs as questions asked and answered during programming tasks. We are not aware of any published empirical study focussing on information needs and current tool support in requirements engineering.

Ott [5] reports on an empirical study that examined typical defect type distributions in current natural language requirement specifications for a car manufacturer. The results confirm that the most critical and important quality criteria in the investigated natural language requirement specifications are consistency, completeness, and correctness. Our qualitative and quantitative findings support this as requirements' characteristics and associations between them were among the most frequently needed information by the participants of our study.

Carrillo de Gea et al. [2] report on a study to get insights how current requirements engineering tools adapt to requirements engineering activities. They surveyed the vendors and assessed tool features in three concrete scenarios. Their findings give an overview of current landscape of requirements engineering tools and their features from the vendors perspective. They suggest that improvements for modeling and requirements management is still needed. We focus on the perspective of the tools users (i.e., stakeholders) and

study different situations such as requirements understanding and negotiation. Our results suggest the need to improve current tools, in particular, for providing information about requirements metadata and dealing with the preferences and evaluations of multiple stakeholders.

VII. CONCLUSIONS

We conducted two case studies with two companies and surveyed 307 requirements engineering practitioners from multiple organizations and with different demographics. The goal was to identify information needs and assess the tool support to supply these needs in practice. Our results clearly show a gap between what information stakeholders need to know and how current tools supply this information.

The biggest gaps were on information about requirements properties and associations (such as needed resources and related requirements), preferences of other stakeholders (such as preferred vocabulary or estimated quality), and conflicting preferences of stakeholders. In particular the support for the negotiation and prioritization of requirements is unsatisfactory.

While the stakeholders overall agreed on the importance of the information needs and the degree of tool support, we also identified significant differences between them. For instance, managers and requirements engineers were less satisfied than developers and testers with the tool support for most information needs. All types of tools (RE tools, Wikis, Office tools, and issue trackers) performed rather low. When comparing the tools among themselves, we found that the satisfaction with RE tools was slightly higher, in particular for accessing requirements metadata and relationships.

In large, distributed projects, an improved intelligent support for RE is needed. For a successful deployment of such systems in RE, researchers and tool vendors need to tackle issues concerning the privacy of stakeholders and the integration of these tools into stakeholders' workflows.

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