Understanding Requirements at Estimation Time: An Open Issue for Research

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Abstract. Understanding the client requirements at estimation time is critical to deliver a budget. The process of building such understanding not only depends on the software company, but also it changes from project to project, and should be conducted under several restrictions. This paper presents a study that analyzes the practices used by Chilean small and medium-sized software companies to build such understanding, and the effectiveness of those practices. The study results indicate that the current practices have low cost-effectiveness, and the literature does not show clear proposals to address this problem. In this sense, the study findings open several opportunities to advance the state-of-the-art with proposals that impact directly on the software industry.

Keywords— Project uncertainty, requirement clarity, software project estimation, small and medium-sized software companies.

I. INTRODUCTION

The constant evolution of customer markets, the increasing demand for highly customized products, and the heterogeneity in user preferences, have triggered an exponential growth in the complexity of software. Competition and customers demand software development projects to run on budget and time-to-market restrictions, but keeping high quality. Appropriately balancing the expectations-cost-time equation is a critical success factor for projects. The software estimation activity plays a critical role in reaching such balance, as it characterizes the goal and scope, estimates the effort, and produces an initial plan and budget, determining thus the feasibility of the proposal. Affordably and rapidly producing accurate estimates is crucial, and even more for small companies given their potential vulnerability [1, 2].

The literature reports multiple factors affecting software development effort estimation, e.g., the lack of historical information [3], the estimators' knowledge and expertise [4] and project uncertainty [5, 6]. However, the criticality of the factors depends on the size of the company [1] and on the geographical region [7]. In order to identify the most influential factors on software estimations in small and medium-sized Chilean companies, we conducted semi-structured interviews to 47 software estimators from twelve companies. We asked them the relevance of 37 factors, grouped in eight categories: team, requirements, product, technology, project, operation, management, and business. These categories and their factors were defined considering the key situational elements of the framework proposed by Clarke and O'Connor [8], and also the literature of the area.

The analysis of the interview results shown a particular factor as the most relevant one: "*the clarity of the requirement*". Using a 5-point scale, 40 out of 47 participants rated this factor as highly influential, and the other seven people rated it as influential. This result is not surprising, since it is aligned with previous research that emphasize the role of the requirement clarity not only in software estimations, but also in the development project [2, 5, 6, 9]. The cone of uncertainty also recognizes this aspect as a key factor to consider during the estimation and management of software projects [10]. Clearly, the relevance of this factor is universal.

Figure 1 shows this cone and the three typical areas were the estimators can be at the time to produce an estimate and deliver a budget for a particular project, considering the clarity of the requirements and their expertise on the project domain. In the risky zone the uncertainty about the project to address is too high, therefore it is not recommended to estimate. Instead, the estimators should gain understanding on the requirements until reaching the affordable or safe zone. For each project, the accuracy of the estimates strongly depends on the zone in which the estimators are at the time to perform the estimation.
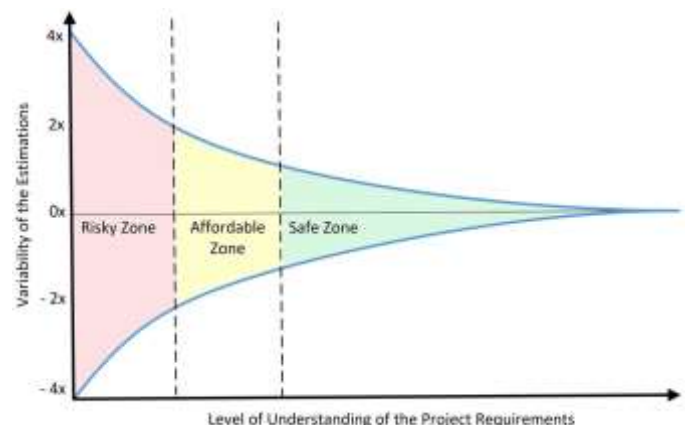

Figure 1. The uncertainty cone at estimation time
(based on [10], p. 38)

The cone's shape and also the zones' size change from company to company. However, all of them have to deal with the project uncertainty at the time to estimate. In order to

understand both, the activities conducted by Chilean software companies to clarify the project requirements at this stage, and also the capability that these activities have to move the estimation scenario from one zone to another, we conducted a survey to 228 software estimators from 62 small and medium-sized software companies. This survey tries to answer the following research questions:

RQ1: What activities do companies perform to gain understanding on the project requirements at estimation time?

RQ2: Are these activities cost-effective?

The answer to these questions allows us inferring the capability of these practices to move the estimation scenario forward in the cone and the rationale for using these practices. Moreover, it can help us characterize the estimation scenario to propose alternative cost-effective practices for these companies. A recent study shows that the local culture of a country or region influence the development processes, and eventually make them different [11]. Therefore, understanding the reality of a particular country (like Chile) or a region is necessary to propose improvements to particular practices, like gaining clarity of the requirements at software effort estimation time.

The next section discusses the related work. Section III describes the study. Section IV presents the results and answers the research questions. Section V presents the threats to validity. Section VI concludes discussing the implications of our findings for the academy and industry.

II. RELATED WORK

The literature reports several elicitation practices that could be used to clarify the requirement, e.g., interviews, task analysis, domain analysis, card sorting and prototyping [12]. However, the usual constraints under which the companies have to deliver the estimate (i.e., quickly and with low effort), jeopardize the feasibility of using these techniques. Typically, the probability to actually sell the project under estimation is uncertain, and the effort required to deliver a budget is assumed by the software provider. In this sense, the techniques for requirement elicitation could be used when the company has a high probability to get the contract, but in other cases, only the most simple ones (e.g., interviews) could be used.

Unfortunately, most companies have no option but to estimate almost any request as a way to keep their operations running, particularly those companies that are still not business stable [13]. Therefore, these companies require cost-effective practices that consider the constraints under which they have to deliver the estimates.

Jørgensen shows the estimation process involves three stages [14]: effort estimation, planning, and bidding. Most estimation approaches are focused on addressing these stages, but none of them formally consider the requirements discovery stage that must be done previous to the estimation. Only expert-judgement-based approaches informally considers this stage [15], assuming the experts are going to interact with the client

to clarify the requirements before to estimate. This could explain why expert-based techniques are the most widely used in the software industry [16].

Summarizing, the stage of requirements discovery is not formally considered in the estimation process, and (to the best of our knowledge) the literature does not report empirical studies that help identify the practices used by the industry to conduct this activity. In the next section we describe the study conducted on Chilean software companies to gain understanding on both, the practices they use for requirement discovery and the effectiveness of these practices.

III. STUDY DESCRIPTION

The study was a survey in which we used a structured questionnaire to gather the opinion of the participants. These people filled out the questionnaire through Internet as a way to ease their participation. Next we describe the main design aspects of the survey.

A. Questionnaire Design Process

The questionnaire was designed following the proposal of Kitchenham et al. [18]; i.e., considering the research questions to answer, we defined a set of particular questions that allows us to gather the knowledge to be captured from the participants. We revised the writing of the questions to ensure their understandability, and then defined the sequence of questions that eases the process to fill out the questionnaire.

Each question can be answered using multiple-choice. In this sense, we proposed and revised the options included as answers, trying to ensure understandability and representativeness. Most questions included an option "other" among the possible answers, not only to allow participants to respond accurately, but also to identify the representativeness of the options given to answer the questions. These questions were organized in three tracks considering the nature of the information to be gathered.

After designing the questionnaire, it was improved through three reviewing cycles where it was analyzed and then revised based on the reviewers' comments. The reviewers were estimators from a particular software company, and the reviews were focused on determining the understandability of questions and answers, and also identifying the sufficiency of the answers to respond to the research questions. The reviewing sessions were also used to identify potential biases in the writing or presentation of the questions and answers.

B. Questionnaire

The questionnaire includes three tracks designed to gather information about 1) *the participants*, 2) *the practices they use to clarify the client requirements at the estimation time*, and 3) *the effectiveness of those practices*, respectively.

Concerning the participants, the people had to indicate their main role into the organization, and the possible answers were (i) general manager, (ii) business manager/salesperson, (iii) project manager/team leader, (iv) architect, (v) developer, and

(vi) other. Then, they had to rate their seniority in the estimation of software projects or part of them; and the possible answers were (i) trainee (less than one year playing the role), (ii) novice (at least one year playing the role), (iii) experienced, and (iv) expert.

Concerning the practices to clarify the clients' requirements, the participants had to indicate the activities that they regularly perform to deal with this challenge. Particularly we asked: *after receiving a budget request, what activities do you regularly perform to gain understanding on the client's requirements?* The possible answers were (i) I search for information on the Internet, (ii) I met with the client, (iii) I analyze documents provided by the client, (iv) I perform a pilot project or a design sprint (one week), (v) I conduct a high-level requirement elicitation, and (vi) other. For this question, the participants could select up to three options. Additionally, we asked: *how much effort do you regularly spent in conducting these activities?* The possible answers were: (i) low, (ii) medium, and (iii) high. The answer to this question was single option.

Concerning the effectiveness of these practices we presented three questions. The first one was: *after conducting the clarification process, how clear is usually the client requirement for you?* The options were: (i) I have a general idea of the requirements, (ii) I have a refined idea of them, and (iii) I have a detailed specification of it. This was also a single choice answer. The second question was: *according to your experience, is such information enough to estimate the requirement?* The options were: (i) it is enough, (ii) I can manage it, and (iii) it is not enough. The third question depends on the previous answer. If the participant answered "it is not enough", we asked: *why the information of the requirement is usually not enough? Please indicate the most frequent reasons.* The possible answers were: (i) I have little experience in similar projects, (ii) the project is large or complex, (iii) the problem to address is fuzzy, (iv) the project goal is not clear, (v) I am not able to imagine the solution, (vi) I had no resources to refine the requirements, (vii) the client had little or no availability to clarify the requirements, and (viii) other. The participants can choose up to three options.

If the answer to the second question was "it is enough", then we asked the most frequent reasons (similar to the previous case), and the possible answers were: (i) I have experience in similar projects, (ii) the project is simple or small, (iii) I had the resources to refine the request, (iv) the client was available to clarify doubts and provide more information, (v) I know the solution, (vi) the project goal is clear, (vii) the problem to address is clear, and (viii) other.

If the answer to the second question was "I can manage it", we used the same possible answers as for the case of "it is enough". While both insufficient and sufficient reasons would have been interesting, we preferred to ask solely the sufficient ones. The rationale was to detect why the participants

considered they can manage to get out from the risky zone to the affordable zone (see Fig. 1), and not why they cannot reach the safe zone.

In order to reduce the bias in multiple choice answers, the options were shown in a random order. The platform used in the survey automated the sequence of questions shown to the participants, and it presented only one question (and their answer options) per stage to these people. The participants were able to revise their previous answers, and they also had to accept the terms of participation by clicking a check-box in the first Web form.

C. Selection of Participants

Inclusion and exclusion criteria were defined to determine the companies and people that can participate in this study. The inclusion criteria for the companies considered: 1) be a Chilean company, 2) have between 10 and 200 employees, 3) at least 75% of the employees should be involved in the software development business, 4) be at least three years old, and 5) develop software for clients outside the company. The exclusion criteria were the following: 1) the core business of the company is not software development, and 2) do not have an institutional email address to receive an invitation to participate in the survey.

Concerning the participants we defined only one inclusion criterion: the people have to frequently conduct estimations of whole projects or part of them during the last twelve months. This included technical and business people. No exclusion criteria were defined for them.

Considering these participation criteria, we used information from three formal directories of software companies to identify potential candidates to participate in the survey. The information sources were two IT enterprise associations in Chile (ACTI[1] and Chiletec[2]) and the list companies reported in [11]. After this first selection, we identified 84 candidate companies. Then, we sent an invitation to participate in the survey to the institutional email address of these companies, indicating the inclusion and exclusion criteria. We asked them to answer indicating their willingness to participate and confirm that they accomplish the criteria defined for software companies. After this process, 62 companies indicated to be available to participate and accomplish the participation criteria.

The selection of employees that filled out the questionnaire was done by the own company, after we indicated to them the minimal criteria of participation for these people. We verified the accomplishment of the participating criteria using the information provided by the people through the questionnaire.

D. Information Gathering Process

The information gathering process followed the guide proposed by Singer et. al. [5]. Particularly, the survey introduction presented its context and purpose, asked the

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participants to indicate if they accomplish the participation criterion, and finally it asked for consent to record their answers.

The questionnaire was opened for answering for three weeks. The participants answered the questions using multiple choice as indicated before. The platform assigned an anonymous identifier to the participants, which allows us to relate all their answers. Only complete answers were considered in the results processing.

E. Information Processing Strategy

After the deadline, the questionnaire was closed and the received answers were exported to a spreadsheet. We discarded uncompleted answers and also those from people who do not indicate to satisfy the participation criteria. Afterwards, the valid answers in the spreadsheet were imported in Tableau[3].

The data was analyzed in terms of the three tracks defined in the questionnaire, *the participant*, *the practices they use to clarify the client requirements at the estimation time*, and *the effectiveness of those practices*. Also, a cross-track analysis was performed, and the potential findings were identified. Following the guide from Kitchenham et al. [18], the data was reviewed to discover inconsistencies in the answers. Finally, we answered the research questions using the findings extracted from processing the results.

IV. ANALYSIS OF RESULTS

A total of 228 people (out of 334 participants) answered all questions and satisfied the participation criterion; they belonged to 62 different software companies. The average time they spent to complete the questionnaire was 4:13 minutes.

Concerning their roles, 48% were developers, 26% were project manager/team leaders, 14% were architects, 9% were general manager, and 3% were business managers/salespersons.

Concerning the seniority in performing estimations, 48% declared to be experienced, 14% were experts, and 38% were novice (at least one year of experience). Nobody declared to be a trainee. The answers of the participants, considering the different roles, were highly consistent. The Cronbach's alpha of their answers was 0.76 indicating a high correlation among them. Next, we revisit the research questions and present the results that allow us to answer them.

A. Answering RQ1

Concerning RQ1 (*what activities does the company perform to gain understanding on the project requirements at estimation time?*), we explicitly asked participants about what activities they regularly perform. We obtained similar answers independently of the participant role and experience. Figure 1 shows the results by means of a force-directed graph. Each node represents a clarification activity and the node size represents the number of answers for the option. As participants can answer up to three options, we use an arc to represent that two answers were used together to clarify the requirement. The width of the arc represents the frequency of the combination.

Meeting with clients and conducting high-level requirement elicitation (that requires prolonged meetings with the client) are the most frequent activities. Moreover, some companies perform pilot projects or design sprints, that demand a higher involvement from clients. More than 94% of the participants declared that they perform at least one of these three clarification activities. Thus, *clients are usually available to provide information about their requirements (finding 1)*.

Participants also declared the level of refinement of the requirements that they usually obtain from the clarification activities: 34% reach a general idea of the requirements, 49% obtain a refined idea, and only 17% produce a detailed specification. Thus, *interacting with clients produces mostly a refined idea of the requirements (finding 2)*.

A | I met with the client
B | I conduct a high-level requirement elicitation
C | I analyze documents provided by the client
D | I search for information on the Internet
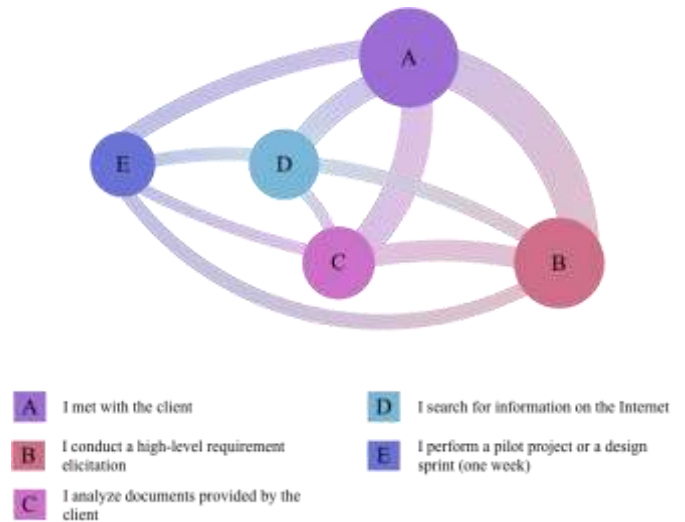E | I perform a pilot project or a design sprint (one week)

Figure 1. Practices more frequently used to clarify the client requirement.

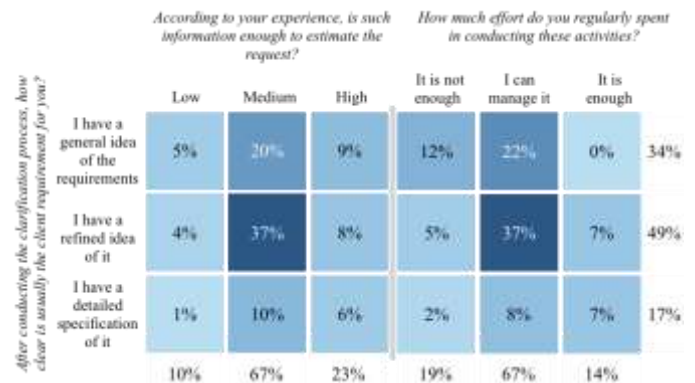

Figure 2. Outcome of the clarification activity vs. the effort spent and its sufficiency to support estimations.

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[3] https://www.tableau.com

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In order to characterize how deep in the uncertainty cone participants can reach with the activities they perform, and how much effort they invest, we compare the level of refinement with the declared effort (cost) and the effectiveness (sufficiency). Figure 2 summarizes the results.

Concerning the effort, 90% of the participants invest medium or high effort to clarify the requirements, and 83% obtain at most a refined idea as a result of such effort. Concerning the sufficiency, 19% of the participants declared that they end up estimating in the risky zone, i.e. that the outcome of the clarification activity is not enough. A 79% of the participants feel some confidence when estimating, as 67% reach the affordable zone, and 14% estimate in the safe zone (see Fig. 1). A general idea or a refined idea seem to make estimation feasible, as declared by 66% of the participants, where 59% declared that they can manage and 7% indicated that it is enough. Thus, *reaching at most a refined idea takes medium to high effort and provides confidence to estimators (finding 3).*

B. Answering RQ2

Concerning RQ2 *(are these activities cost-effective?)*, we analyze the effort invested in the clarification activities (cost) versus the sufficiency of the obtained outcome (effectiveness). Figure 3 presents the results. The color of the cell indicates how cost-effective are the clarification activities according to the participants' answers, using a scale from red (low) to green (high cost-effectiveness).

The results indicate that with medium effort, 48% reach at least the affordable zone, and 10% the safe zone. Also, by investing a high effort in the clarification activities, 12% declared that they can manage and 3% that the obtained outcome is enough. Thus, 73% of the participants invest medium or high effort to reach at least the affordable zone.

A 17% of the people invest medium (9%) or high (8%) effort, however the outcome of the clarification activity is still not enough. With low effort, 7% declared that they can manage it, and 1% that it was enough.
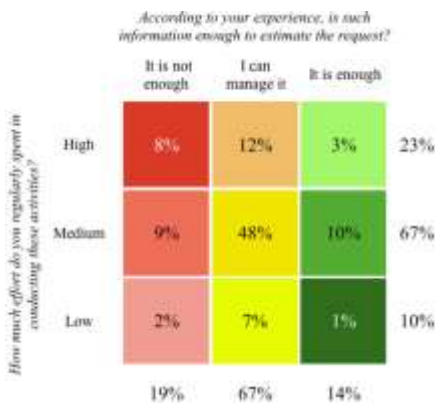

Figure 3. Effort spent vs its sufficiency to clarify requirements.

Only 18% of the participants get at least the affordable zone with low effort, or the safe zone with medium effort. A 82% of

the participants either cannot reach the affordable zone, or reach it with at least medium effort, or the safe zone with high effort. As a consequence, *the activities performed to clarify requirements are not cost-effective (finding 4).*

V. THREATS TO VALIDITY

This study considers construct, internal and external validity as characterized in [17].

Construct validity. We used a web-based questionnaire with randomly-sorted multiple-choice answers to avoid experimenter expectancies bias. We invited participants by email declaring software effort estimation to be the context of the study, but without explicitly revealing its actual goal, avoiding thus hypothesis guessing bias. Also, we did not ask for the company or participant name to avoid evaluation apprehension bias. To address the mono-method bias, we used interviews to successfully corroborate the preliminary findings obtained during the test of the questionnaire in one company. By this test we also found that novice answers did not alter the preliminary findings, avoiding the bias of confounding constructs and levels of constructs. Finally, participants might have different perceptions on what low, medium and high effort means, and what an insufficient and sufficient outcome is. For this reason, we analyze cost-effectiveness in a per-answer basis, instead of groups of answers.

Internal validity. The same participant may answer differently if asked about particular estimation requests, as there are several factors affecting the estimation process and the estimates. Hence, history, maturation and testing were potential threats to internal validity. To address this threat, the questionnaire explicitly asked about the activities and scenarios faced frequently. Interviews during the test allowed us to corroborate the usefulness of asking for the usual practice. The actual selection of participants was delegated to each company, as they know the role of their own employees. However, we use inclusion and exclusion criteria to carefully select the companies, and a question in the questionnaire to validate the inclusion criterion of participants. Finally, to avoid threats regarding instrumentation, we use a web-form tool that automates information gathering and use Tableau for data analysis. Data export and import are features of these tools. To verify that no error was introduced by the intermediary spreadsheet used in the data processing, we corroborated that we can reach the same results in Tableau than those reported by the web-form tool.

External validity. Our study targeted estimators from small and medium-sized Chilean companies which main and stable business is to develop software for external clientes. Candidate companies were selected from the two main IT associations in Chile using the characterization on business and size from [11]. We received answers of 74% of the companies meeting the selection criteria, so we claim that our results are representative of the target population. Our findings are not necessarily generalizable to companies located in other regions; we support the claim that improvements to development practices must consider the company size and region as both are critical

factors. However, we foresee the characterization of the state-of-the-practice in other regions by means of our questionnaire to allow future comparisons.

VI. Conclusions and Future Work

Most software estimation techniques assume the client requirements are clear at the estimation time; therefore, they are focused mainly on determining the development effort, planning and bidding. However, a preliminary study of the authors, conducted in small and medium-sized Chilean software companies, indicated that *the clarity of the requirements is the factor that most influences the estimates.* This finding is aligned with other results already reported in the literature, and it shows that the requirements discovery stage is at least as important in the estimation process as determining the development effort, planning and bidding.

This paper makes a step towards understanding what the companies do to clarify client requests and how cost-effective are their clarification activities. The study results indicate that meetings with the clients are the most frequently used activity. Moreover, the results indicate the clients are usually available to provide information about their requirements (finding 1), interacting with clients produces mostly a refined idea of them (finding 2), and reaching at most this refined idea takes medium to high effort and provides confidence to estimators (finding 3). Besides, the activities currently performed by the companies to clarify requirements are not cost-effective (finding 4). In this sense, this paper shows an opportunity for research with a high potential impact on the software industry.

A future line of research is to create an instrument that helps clients and software companies build a shared understanding at the requirements discovery stage. The effort of using such an instrument should be low to ensure its usability and usefulness in practice, and at least equally effective as current practices.

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