Surveys in Software Engineering: Identifying Representative Samples

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ABSTRACT

Context: The representativeness of samples in Software Engineering primary studies is still a great challenge, mainly when identifying available sources for establishing adequate sampling frames, characterizing subjects and stimulating their participation in (opinion) surveys. The lack of survey guidelines taking into account the specificities of Software Engineering increases the research challenge. **Goal:** To introduce a conceptual framework for supporting the identification of representative samples for surveys in Software Engineering. **Method:** Based on knowledge acquired in the technical literature and researchers' experience, to organize a set of guidelines to systematically support sampling in Software Engineering surveys. To perform *in vitro* empirical studies to observe and evolve the guidelines. **Results:** An empirically evaluated set of planning activities and tasks with recommendations to support the identification of representative samples for surveys in Software Engineering is available. **Conclusion:** Surveys have been supporting relevant investigations in Software Engineering in the last decades. This conceptual framework can contribute to strength representativeness of their results. However, some important issues regarding survey research are still open and deserves attention from the empirical Software Engineering community.

CCS Concepts

• General and Reference→ Empirical studies; 500 • Software and its Engineering; 300.

Keywords

Survey; population; sampling; sampling frame; recruitment; Empirical Software Engineering.

1. INTRODUCTION

In the early years of Empirical Software Engineering (ESE) the research efforts were concentrated on conducting controlled experiments [1]. Since then, different qualitative research methods have been applied to support investigations in the field, including case studies [2], action research [3], and focus group [4]. In this context, the versatility of the survey method [5] for supporting both basic and applied research can be observed. Software Engineering (SE) researchers have commonly used opinion surveys for different research objectives, such as *mapping the state of practice* [6, 7], *establishing baselines for investigating research topics* [8, 9], *gathering opinion regarding SE technologies and practices* [10], among others. When properly conducted, opinion surveys (from now on simply called *surveys*) allow researchers to perform descriptive and large-scale investigations without the rigorous level of control required by controlled experiments. Surveys support the characterization of knowledge, attitudes and behaviors from different groups of individuals [11] through the generalization of findings from a fraction of the population (sample) to the whole population.

Although surveys are of common use in ESE, their external validity is still impacted by using *convenience* for sampling [12]. Consequently, even after exhaustive effort spent on sampling and recruitment activities, SE survey executions frequently fail to be *impartial* and *representative*, two essential and expected surveys' characteristics [13]. Moreover, since such effort is typically spent in *ad-hoc* activities [14], SE surveys also frequently fail to be fully *systematic* and, consequently, *replicable*.

One can observe that not only the challenges on characterizing different contexts of SE studies contribute to the presented scenario [15], the business nature of SE also does, typically restricting access to large data sets, containing information about organizations' professionals and projects [16]. Differently, surveys performed in other scientific fields such as *social sciences* [17] and *public health* [18] are commonly supported by country-wide sampling frames.

Thus, a critical issue on impartially establishing representative samples to support SE surveys relies on identifying relevant and accessible sources of populations for organizing adequate sampling frames. Furthermore, establishing representative samples may not be sufficient to assure the representativeness of results since the participation in surveys is commonly voluntary. Hence, a survey plan should also indicate how to systematically encourage responses and prevent non-responses [7], stimulating subjects participation [19].

Therefore, based on the presented survey research issues in SE, the following research questions emerged:

- RQ1. How to identify and assess potentially relevant sources of populations available for conducting surveys in SE?
- RQ2. How to deal with the limitations on retrieving relevant information from these sources?
- RQ3. How to characterize samples for surveys in SE?
- RQ4. How to stimulate participation in surveys in SE?
- RQ5. How to systematize all the sampling and recruitment activities to make them repeatable?

After an investigation over known guidelines for conducting surveys in SE [20], we observed that SE literature provides

ESEM '16, September 08-09, 2016, Ciudad Real, Spain
 ISBN 978-1-4503-4427-2/16/09…$15.00
DOI: http://dx.doi.org/10.1145/2961111.2962632

insufficient guidance to answer such questions. Thus, we organized [21, 22] and empirically evolved [23] a conceptual framework to support researchers on planning surveys in SE through guiding the systematic identification of sources of population and corresponding representative samples. It combines knowledge from the general survey research literature with good practices of applying the survey method in the field, providing a set of *activities*, *tasks*, and *recommendations* for supporting SE researchers on planning their surveys.

Therefore, this paper aims to introduce the conceptual framework (fully described in [23]), going further by discussing some remaining open questions related to the presented research. Section 2 presents related works. Section 3 introduces the conceptual framework. Section 4 discusses open questions related to survey research. Section 5 presents the conclusions.

2. RELATED WORKS

Throughout the last decades, scientific fields with different maturity levels in survey research have been discussing how to improve survey samples' representativeness, such as Marketing [24], Health [25] and, closer to SE field, Information Systems [26]. Pinsonneault and Kramer [26] analyzed 122 survey-based studies in Management Information Systems (MIS), reported in major MIS journals between 1980 and 1990, identifying that 70% of the studies used convenience samples or did not indicate the sampling procedure. Also, the surveys which were frequently analyzed do not follow systematic procedures for sampling and their execution often results in reduced participation rates. There are similarities among issues reported 23 years ago by the researchers in the context of Information Systems research and those exposed in the introduction of this paper. As far as we could look for, we did not find a similar comprehensive investigation in the context of SE although we had found investigations with more restrictive scope [7, 27]. Conradi et al. [27] evaluated a set of surveys on component based SE and concluded that most of them do not make clear how they established their samples. Stavru obtained a similar conclusion [7] when evaluating surveys conducted in academy and industry to investigate the use of agile methods in software organizations. The author states that it is not possible to assure to which extent the results obtained by most of the analyzed surveys could be considered valid.

The few guidelines for conducting surveys in SE identified in the technical literature commonly reproduce concepts and practices from the general survey research, even reporting challenges on the survey planning in SE without providing specific orientation on how to overcome them. Therefore, they barely address the research questions presented in the Introduction. Kitchenham and Pfleeger [5, 28, 29] discuss issues on survey design, emphasizing that researchers must keep in mind the following aspects when sampling from a population: *avoidance of bias*, *appropriateness*, and *cost-effectiveness* [5]. Afterward, the authors introduced the principles of population and sampling, emphasizing that is not possible to sample from a population if such population is unknown [28]. First, the survey's target audience should be derived from the research objective. Next, a list composed of a subset of elements from the audience should be established, comprising the survey sampling frame. Finally, a representative sample should be extracted from this sampling frame. The researchers also present the most common designs to perform sampling (probabilistic/ non-probabilistic) and introduce a statistical formula to calculate the survey sample size. In [29], the researchers proposed the following set of strategies to improve the participation of subjects: *work the participants' motivation, supplying them with key pieces of information regarding the study*; *perform oversampling*; *Plan to send reminders to the participants; Approach individuals personally when needed*.

Kasunic's technical report [30] presented a set of guidelines (hands-on) for conducting surveys in SE, distributed in a set of seven sequential steps: 1) *identify the research objectives;* 2) *identify and characterize target audience*, *design sampling plan*; 3) *design and write questionnaire*; 4) *pilot test questionnaire;* 5) *distribute the questionnaire*; 6) *analyze results; and* 7) *write report*. However, the content of such guidelines is predominantly addressed to introduce the general survey research instead of discussing the survey method tailored to the SE field. For instance, similar to Kitchenham and Pfleeger, the technical report presents general principles regarding sampling activities, such as sampling methods and sample size formulas, but it does not discuss the recruitment of subjects.

Smith et al. [19] investigate the participation of developers in SE surveys. They introduced a set of persuasive factors, borrowed from persuasive research (*reciprocity, consistency, authority, and credibility, liking and scarcity*) and from recommendations observed in the general survey literature (*brevity, social benefit, compensation value and likelihood and timing*). The researchers analyzed to which extent such factors were applied in a set of ten surveys having developers from Microsoft Company as subjects, observing that sending direct e-mail invitations (without using BCC) may influence the response rate. Despite the small sample of surveys analyzed, the authors concluded that the presented factors could serve as starting point for future studies on improving the response rates of surveys in SE.

In addition to the previous guidelines, we have also identified few experience reports discussing survey planning issues. Some of them consider the survey questionnaire composition [31, 32] and data analysis [33] while others discuss sampling issues [27, 34]. Conradi et al. [27] report in depth how they established the sampling frame of a large-scale international survey through an exhaustive process of gathering organizations' data from three countries (Germany, Italy and Norway) and using different data sources for each one, including Yellow Pages. Due to the limitation of information available in the used data sources, the researchers applied different ways of composing the survey sampling frame. For instance, researchers called each organization listed in the Yellow Pages to identify which of them were active and working with the research theme. Ji et al. [34] replicated this survey in a fourth country (China), where a fourth different approach for sampling was applied. The authors then emphasized challenges to establishing representative samples for SE surveys but recommendations to overcome such challenges were not provided.

3. THE CONCEPTUAL FRAMEWORK EVOLUTION

We organized a conceptual framework for supporting the identification of representative samples for surveys in SE. Here, it is important to notice that the meaning of *representative samples* may significantly vary. Kruskal and Mosteller had identified in the specialized literature several meanings for this concept [35]. A commonly used meaning is concerned with providing a statistical coverage of the whole survey population, applicable when researchers have access to census data, which is not common in SE [27]. Therefore, in the context of our research, a *representative sample* defines a subset of units, randomly retrieved from an accessible, heterogeneous and potentially representative population from the point of view of the survey's target audience (target population) attributes [12]. Such definition takes into account the

limitations of research in the SE field, also touching three representative meanings of samples out of the nine described in [35]: (1) specific sampling method; (2) populations' heterogeneity coverage; and (3) representative as typical, on certain known population attributes, such as gender, age, and income.

The conceptual framework evolved from two previous versions until reach its current version, including the following research activities (chronological order):

- To investigate the use of concepts and practices regarding systematic literature reviews for identifying more representative samples for supporting the re-execution of different surveys [36, 37];
- Based on previous results, to develop the first version of the conceptual framework, presented in [21], including examples of using some concepts introduced by the framework;
- To run a proof of concept [16] by using the conceptual framework to replicate a large-scale experiment, with an instrumentation similar to that employed in surveys, including the use of questionnaires;
- To perform a structured review conducted over EASE and ESEM proceedings on how sampling activities have been carried out in SE surveys [14];
- Based on the previous results, to develop the second version of the conceptual framework [22].

The second version has been submitted to use by an external researcher to support the planning of a survey on software process properties. Based on feedback, a few improvements were made in the framework documentation, resulting in a new release (chapter 4 of [23]). Such release was then empirically evaluated through a feasibility study in which we investigated the conceptual framework acceptance (usefulness, easiness of use, intention to use) and the effect of its use on the quality (thoroughness) of survey plans. Although the conceptual framework was considered acceptable, it was also indicated relevant issues on its effective contribution to improving the quality of survey plans. Then, a focus group session was conducted with the same subjects from the feasibility study to understand better whether the framework recommendations could contribute to planning surveys in SE (chapter 5 of [23]). As a result, several improvement opportunities were observed and used to evolve the framework recommendations.

The third and current version of the conceptual framework incorporates the results from all previous research activities. For the sake of space, its concepts are briefly presented in Table 1. Every survey plan must describe (mandatory) the concepts with an asterisk. See the complete concepts descriptions and properties in Appendix A of [23]. One can observe such concepts are, in the majority, already provided by survey/ statistics literature [38, 39]. In fact, we do not intend to rewrite these concepts but instead contributing to organizing and systematize their use in SE surveys. Moreover, we intend to associate them with new concepts proposed by the conceptual framework taking into account the issues of SE research already discussed in the Introduction of this paper.

For instance, suppose a researcher is planning to conduct a survey aiming at investigating the use of systematic literature reviews by Brazilian SE research groups. While the *unit of analysis* could be each research group, the survey *subject* would be each researcher. However, where can we find a representative set of Brazilian SE research groups? Taking into account the several amounts of universities and research institutes in Brazil, some candidates to the *source of populations* could be: (1) a list of research group partners; (2) local conferences proceedings; (3) the CNPq (Brazilian Council for Scientific and Technological Development) research group directory. While (2) could provide a representative set of Brazilian research groups based on the affiliation of the papers' authors, (1) could be significantly restricted by the convenience. However, taking into account the nation-wide scope of (3), such candidate can be considered the best choice[1]. However, the CNPq research group directory includes Brazilian research groups from all Brazilian scientific fields. Thus, a *population search plan* should be established and then executed for retrieving only SE research groups, supporting the composition of the survey *sampling frame*.

Table 1. The concepts of the conceptual framework.

Concept	Description
Target Audience* (target population)	Set of units that could be covered in a survey [38]. The establishment of a survey's target audience tries to answer who can best provide the information needed to achieve the research objective.
Subject *	Characterizes the survey respondent, i.e. the *unit of observation* in survey research [39].
Unit of analysis*	Consists on the primary entity used for analyzing the study [39], which can be composed by one *individual* or a *group of individuals* in survey research
Source of Population	Database (automated or not) from which an adequate population for a specific target audience can be systematically retrieved.
Population Search Plan	Set of procedures and rules established in the survey plan for systematically retrieving an adequate population from sources of population
Sampling Frame*	Listing of units from the survey's target audience available for sampling [38]
Sampling Strategy*	Characterizes how to perform sampling (sampling design) and how many objects should be selected (sample size)
Recruitment Strategy*	Characterizes how to recruit the subjects from the survey sample. It includes the invitation message and the setting of different factors that can influence participation of subjects
Subject/ Unit of Analysis Characterization Questions	Set of questions for characterizing the survey subjects/ unit of analysis through additional attributes required by the survey plan but not available in the source of population

Besides, the conceptual framework provides a set of eight activities distributed into the typical survey planning process (Figure 1) to support the use of the concepts presented in Table 1. Once the *research objectives* have been identified, the survey's *target audience* (TA) should be characterized, which includes determining who are the survey *subject* and the survey *unit of analysis*. If there is no known sampling frame available to support the survey execution (as exemplified above), it should be first selected a *source of population* (SP) to be then submitted to a particular *population search plan* (PS). Based on the results of the search plan execution, the survey *sampling frame* (SF) should be

[1]Indeed, the conceptual framework provides resources for researchers rigorously evaluating and comparing the available candidates.

composed. Then, a *sampling strategy* (SS) should be designed. If the survey sampling frame does not provide sufficient information regarding the subjects/unit of analysis, specific *characterization questions* (CH) should be developed and introduced in the questionnaire. Although the design of the questionnaire is out of the scope of the conceptual framework, it can be a useful input for supporting the design of the recruitment strategy (RS).

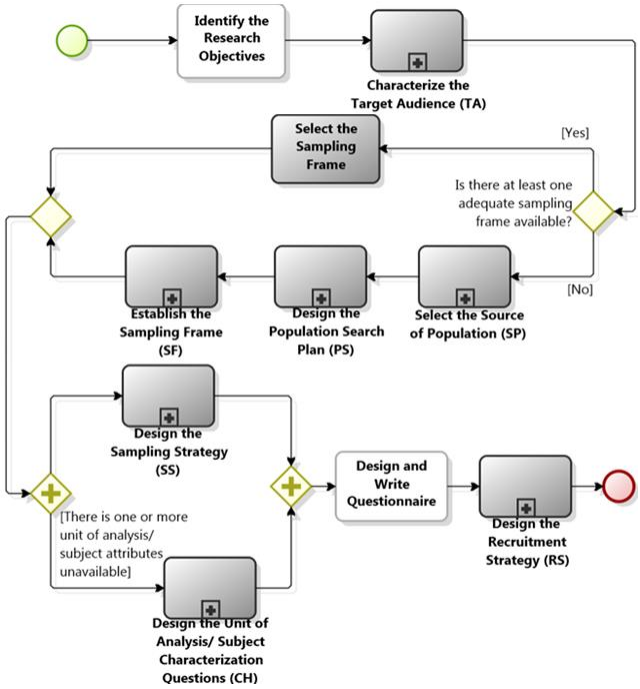

Figure 1. The conceptual framework activities (shadowed) inserted in the survey planning process.

Each framework activity is composed of one or more *tasks*, as exemplified in Table 2 to the activity PS. Besides, each task can be supported by one or more *recommendations*, as illustrated in Table 3. Chapter 6 of [23] presents the complete description of the conceptual framework activities, tasks, and recommendations.

Table 2. Design the population search plan (PS) tasks.

Task ID	Description
PS01	*Design the search algorithm*. A search algorithm must be designed to describe how the population will be searched in the selected source of population
PS02	*Design the search string*. The use of search strings can be helpful on filtering the suitable search units to the survey context. Depending on the specialization of the source of population and on the search resources available, even complex strings may be needed, using logical operators as commonly used in systematic literature reviews (SLR).
PS03	*Design the inclusion/ exclusion criteria.* Design the set of criteria that will be used to qualitatively filter the results from the execution of the search algorithm

We are currently inviting partners from different SE research groups to use the conceptual framework for planning their surveys. After designing the survey plan, the researcher can answer a follow-up questionnaire to present his/her opinions regarding the framework acceptance and use. So far, we have received responses from two external researchers giving positive feedback regarding its usefulness, besides some suggestions to improve its easiness of use without changing its contents. Therefore, we have decided to share the conceptual framework with the ESE community, which is also a significant opportunity for identifying new opportunities of evaluating and consequently evolving the presented technology.

Table 3. PS tasks and their recommendations.

Task ID	Recommendation(s)
PS01	R17**.** In order to support the survey plan reuse, the search algorithm should describe any particularities and restrictions on manipulating the source of population. For instance, if the source of population is provided by a Web application, it is important to describe how to access and apply the search unit (parameters, option, menus). Have in mind that such resources may change in the future.
PS02	R18. Consider consulting the specialized literature (especially standards such as IEEE vocabulary for SE) and/or specialists for identifying a wide range of relevant and similar expressions for composing the survey search string. If an SLR was previously performed in the context of your research, consider reusing its own search strings and data provided by its results.
PS03	R19. If the search unit allows retrieving groups of units of analysis instead of a single unit of analysis, identify relevant attributes to characterize each search result. Such attributes can be helpful to compose your inclusion/ exclusion criteria. For instance, [12] established *LinkedIn's group of interest* as search unit and *individual* as the unit of analysis. In this sense, the authors used group attributes such as its name and its description to support their decision on including/excluding each group of interest identified.
	R20. Use inclusion/exclusion criteria only if it is actually necessary to reduce noise in your population. If you are sure that all search units retrieved from the source of population will be valid, avoid introducing selection bias in the exclusion/inclusion criteria.
	R21. Evaluate if the inclusion/exclusion criteria are composed of one or more conditions that can be automatically verified. If so, consider to insert them into the search algorithm/search string

4. SOME OPEN ISSUES ON SURVEY RESEARCH IN SE

As far as we could observe, there are some open questions concerned with survey research that should be discussed in the light of the maturity of surveys in the SE field, revealing interesting opportunities of future works.

1) How can we assure the accessible population is representative of a specific survey target audience? One can argue that if we cannot have access to census data regarding the survey's target audience, we cannot infer that any accessible population is "representative." For instance, it is questionable to conduct a nation-wide electoral pool through a random sample of *Facebook* members from such country, despite the sample size. However, with few exceptions [6, 27], we do not have census data available in SE research or it implies on prohibitive costs. Who are the Java programmers? What are all software houses spread in the world? Who are the project managers in the country? As a consequence, such condition would restrict the SE survey research

to pretty specific target audiences. Alternatively, through the followed concept of *representativeness* in our research (Section 3), we propose analyzing the heterogeneity of the accessible population. Once we have observed few examples of surveys concerned with the representativeness of their samples (apart from those conducted in the context of this research), one can see the examples cited in the conceptual framework are restricted to a small set. In this sense, we expect the support provided by the conceptual framework will guide researchers in reflecting on the best available candidate for the source of population, mitigating the use of convenience.

2) How to characterize the samples for surveys in SE (RQ3)? Such question addresses the challenge of characterizing the discrete context of studies in SE [15, 40]. Which attributes we should use for characterizing, for instance, an SE practitioner? Age? Academic degree? Current role? Although it is still an open question, we believe that investigating the planning and conduction of previous surveys could be useful for reflecting about which variables can be used to characterize subjects and units of analysis in future works. In this sense, our initial investigation over two significant ESE venues (EASE and ESEM) proceedings allowed us identifying some trends [14] for characterizing individuals and organizations resulting in some conceptual framework recommendations. Besides, we have also observed little concern on using characterization data for interpreting survey results, suggesting their report as a mere matter of formality. Indeed, there are many other surveys presented/published in different venues and journals that should also be investigated, leading to the conduction of a comprehensive mapping study as part of future work. However, data collected from EASE/ESEM surveys suggests there is a long road ahead.

3) How to stimulate participation in surveys in SE (RQ4)? Different factors can be used to boost the participation of subjects [19, 41] and the conceptual framework addresses this concern. However, we are far from understanding the practical impact of such factors on the participation of subjects in SE surveys. For instance, in which extent the use of rewards could stimulate the involvement of software professionals in surveys? Is it worthwhile to send personalized invitations? In an ideal scenario, the participation rates obtained in surveys executions following different recruitment strategies could be compared, but one can see surveys re-executions are still uncommon in SE [14]. Thus, we could alternatively perform such investigation through using data from a large set of different surveys already conducted in the field, as presented in [19]. However, to be included in such investigation, we point out it is necessary that a survey should provide, at least: (1) a clear description of the followed sampling design (probabilistic or not); (2) the control of the recruited subjects (and the set of respondents), in order to calculate participation rate; and (3) a clear and systematic strategy followed for recruiting all survey subjects. Thus, since only a few surveys analyzed in the context of our research [14] presented such characteristics we could not observe a significant influence of any factor in the participation of subjects. Besides, we found that some persuasive factors, such as the use of rewards and humor were barely used.

4) How the use of different sampling designs can be explored in the field? Different target audiences and research objectives will demand more/less effort on sampling, which is not necessarily related to the population size. For instance, a survey specifically designed to a local organization may need stratifying its population by different departments and roles, while a large-scale international survey of SE professionals may not demand stratification efforts. In this sense, one can see the conceptual framework barely presents recommendations in the *design the sampling strategy* (SS) activity. In fact, most of the observed surveys in the technical literature relies on the use of accidental sampling or even not clearly characterizes the sampling frame. For instance, as far as we are aware [12, 27] are the only works exploring stratified sampling in the SE field. As a consequence, the conceptual framework strictly introduces alternatives to sampling design without discussing them. We understand such gap on exploring more complex sampling designs is related to the already mentioned limitations discussed in the three previous questions. However, additional examples of using different sampling designs could also be identified in a comprehensive mapping study.

5. CONCLUSIONS

This work introduced a conceptual framework to support researchers on planning surveys in SE through guiding the systematic identification of sources of population and corresponding representative samples. It was conceived based on findings from individual cases and *in vitro* empirical studies conducted over its evolution. We cannot ignore that surveys have been supporting relevant investigations in SE in the last decades. In this sense, the presented research is concerned with the understanding that evolving the use of a particular research method in a particular field implies on also investigating knowledge emerged from previous efforts on using such research method in the same area. Therefore, it should have a synergistic relationship between the proposed technology and the state of practice to both continuously evolving together.

In addition to the opportunities for future works presented in Section 4, as an immediate consequence, we expect to improve the easiness of using the conceptual framework and better exploring its usability by providing a web-based environment to support its instantiation. One approach under study is providing support to all survey planning and execution activities by integrating the conceptual framework content to resources of questionnaire design and publishing, typically provided by open survey tools, such as LimeSurvey (www.limesurvey.org).

6. ACKNOWLEDGMENTS

This work has been performed under the CNPq (305929/2014-3) ESE Project. Prof. Travassos is a CNPq researcher.

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