ICS 500: Research Methods and Experiment Design in Computing

Lecture

Case Study

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Lecture Objectives

- ✓ The context of case study
- ✓ The design of a case study and planning for data collection
- ✓ The process of data collection
- ✓ Issues on data analysis reporting

Definitions of Case Study

- Three commonly used definitions of **case study** research are provided by Robson, Yin and Benbasat et al.
- The three definitions agree on that case study is an empirical method aimed at *investigating contemporary phenomena (facts, experiences etc) in their context.*
  - Robson calls it a research strategy and stresses the use of multiple sources of evidence,
  - Yin denotes it an inquiry
  - Benbasat et al. make the definitions somewhat more specific, mentioning *information gathering from few entities* (people, groups, organizations), and the *lack of experimental control.*

What is a Case Study

- A case study is:
  - An empirical enquiry (e.g., practical, experiential enquiry) that
  - draws on multiple sources of evidence (e.g., people, documents)
  - to investigate one instance/ case (or a small number of instances)
  - of a contemporary (modern) software engineering phenomenon (facts, experiences, happening)
  - within its real-life context (situation),
  - especially when the boundary between phenomenon and context (e.g., experiences, company, project, team, situation) cannot be clearly specified.
    - How much expert judgment (phenomenon) is required for example to do cost estimation in a project (context)

Case Study

- The term case study is used in parallel with terms like *field study* and *observational study*, each focusing on a particular aspect of the research methodology

- The case study methodology is well suited for many kinds of software engineering/ computer science research, as the objects of study are contemporary phenomena, which are hard to study in isolation.

- Case studies provide *deeper understanding of the phenomena* under study in its *real context*.

Case Study

- A case study is conducted to investigate a single entity or phenomenon in its real-life context, within a specific time space.
- The researcher collects detailed information on, for example, one single project during some period of time.
- A case study can be applied as a comparative research strategy.
  - For example, you want to evaluate or compare that your proposed solution is better than the existing one in the real-world environment.
- Case studies are very suitable for industrial evaluation of software engineering methods and tools.

Case Study

- As case studies are different from analytical and controlled empirical studies, they have been criticized for *being of less value*, *impossible to generalize* from, being *biased* by researchers etc.

- The critique may be addressed by applying proper research methodology practices and accepting that knowledge is not only statistical significance.

- A case study may contain elements of other research methods,
  - For example, a *survey* may be conducted within a case study, a literature search often precede a case study.
  - Ethnographic methods, like *interviews and observations*, are mostly used for data collection in case studies.

Characteristics of Case Study

- The key characteristics of a case study are:
  - *It is of flexible* type, coping with the complex and dynamic characteristics of real-world phenomena, like software engineering.
  - Its conclusions are based on a clear *chain of evidence*, whether qualitative or quantitative, collected from multiple sources in a planned and consistent manner.
  - It *adds to existing knowledge* by being based on previously established theory, if such exist, or by building theory.

Case Study Control and Realism

- Conducting research on real-world phenomena implies a constant trade-off between level of control and degree of realism.
- The realistic situation is often complex and nondeterministic, which hinders the understanding of what is happening, especially for studies with explanatory purposes.
- On the other hand, increasing the control reduces the degree of realism.
- Case studies are by definition conducted in real-world settings, and thus have a high degree of realism, mostly at the expense of the level of control.

Case Study Process*

- Case study plan and design
  - Objectives are defined and the case study is planned
- Preparation for data collection
  - Procedures and protocols for data collection are defined
- Collection of data
  - Data collection procedures are executed on the studied case
- Analysis of collected data
  - Data analysis procedures are applied to the data
- Reporting
  - The study and its conclusions are packaged in feasible formats for reporting

** As case study methodology is a flexible design strategy, there is a significant amount of iteration over the steps.*

Case Study Planning

- A plan for a case study should at least contain the following elements:
  - Objective: what to achieve?
  - The case: what is studied?
  - Research questions: what to know?
  - Methods: how to collect data?
  - Selection strategy: where to seek data?

Case Study Planning - Objective

- What is expected to be achieved with the study?
- The objective is refined into a set of research questions, and these are answered through the case study's data collection and analysis.
- The objective of the study may be, for example, exploratory, descriptive, explanatory, or improving.
- The objective is initially more like a focus point that evolves during the study.
- Example statement of objective
  - To investigate if a new process can perform better that the existing process.

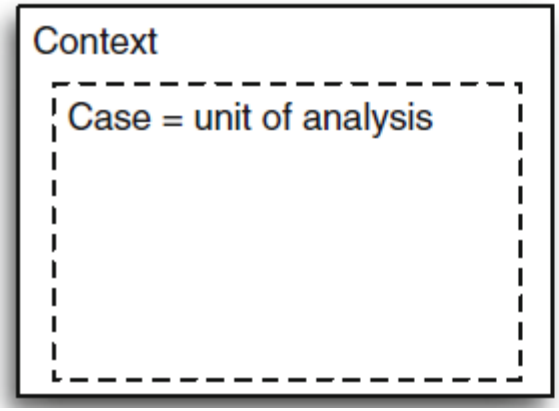
Case Study Planning – The Case

- In software engineering/ computer science, the case may be a software development project, a group of people, a process, a product, a policy, a role in the organization, an event, a technology, etc.

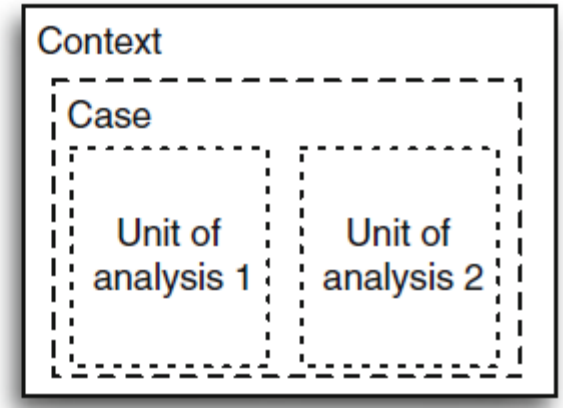
- The project, individual, group etc. may also constitute a unit of analysis within a case
  - Example if the CASE is "Open-Source Software Development" then the "evolution of the software" may be the unit of analysis and the case study = study of open-source software development.
  - Example if the CASE is "Pair Programming" then the "development team" may be the unit of analysis and the case study = study of pair programming.

Holistic and Embedded Case Studies

- If a researcher is examining what kinds of college students are most successful in their careers
  - Case = student & unit of analysis= successful students
- But also wants to examine what kinds of colleges produce the most successful graduate students
  - Case = student & unit of analysis 1= successful students & unit of analysis 2= colleges
- Context = college education



Holistic case study



Embedded case study

Case Study Planning – Research Questions

- The research questions state what is needed to know in order to fulfill the objective of the study.

- Research questions are statements about the knowledge that is being sought, or is expected to be discovered, during the case study.
  - Why do programmers fail to document their code?
  - How does software evolve over time?

- Ensure the questions can be answered with a case study.

Case Study Planning – The Method

- Three categories of methods:
  - Direct (e.g., interviews),
  - Indirect (e.g., tool instrumentation), and
  - Independent (e.g., documentation analysis).

Case Study Planning – Selectin Strategy

- In case studies, the case and the units of analysis should be selected intentionally.
  - This is in contrast to surveys and experiments, where subjects are sampled from a population to which the results are intended to be generalized.
  - The purpose of the selection may be to study a case that is expected to be 'typical', 'critical', 'revelatory' or 'unique' in some respect, and the case is selected accordingly.
- In a comparative case study, the units of analysis must be selected to have the variation in properties that the study intends to compare. However, in practice, many cases are selected based on availability, which is similar for experiments.
- Case selection is particularly important when replicating case studies.
  - A case study may be literally replicated, i.e., the case is selected to predict similar results, or
  - It is theoretically replicated, i.e., the case is selected to predict contrasting results for predictable reasons.

Case Study Planning – Case Study Protocol

- A case study protocol defines the detailed procedures for collection and analysis of the raw data, sometimes called field procedures.
  - It serves as a guide when conducting the data collection.
  - The processes of formulating the protocol makes the research concrete in the planning phase, which may help the researcher to decide what data sources to use and what questions to ask.
  - Other researchers and relevant people may review it in order to give feedback which can lower the risk of missing relevant data sources etc.
  - It can serve as a log or diary where all data collection and analysis is recorded together with change decisions based on the flexible nature of the research.

Case Study Planning – Case Study Protocol

Table 5.1 Outline of case study protocol according to Brereton et al. [25]

Section	Content
Background	Previous research, main and additional research questions
Design	Single or multiple case, embedded or holistic design; object of study; propositions derived from research questions
Selection	Criteria for case selection
Procedures and roles	Field procedures; Roles for research team members
Data collection	Identify data, define collection plan and data storage
Analysis	Criteria for interpretation, linking between data and research questions, alternative explanations
Plan validity	Tactics to reduce threats to validity
Study limitations	Specify remaining validity issues
Reporting	Target audience
Schedule	Estimates for the major steps
Appendices	Any detailed information

[25] Brereton, P., Kitchenham, B.A., Budgen, D.: Using a protocol template for case study planning. In: Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering. University of Bari, Italy (2008)

Preparation and Collection of Data

- There are several different sources of information that can be used in a case study.
- It is important to use *several data sources* in a case study in order to limit the effects of one interpretation of one single data source.
- If the same conclusion can be drawn from several sources of information, this conclusion is stronger than a conclusion based on a single source.

Preparation and Collection of Data - Data Collection Techniques

- *Direct methods* means that the researcher is in direct contact with the subjects and collect data in real time.
  - Examples: interviews and focus groups.
- *Indirect methods* where the researcher directly collects raw data without actually interacting with the subjects during the data collection.
  - Examples: logging of the usage of software engineering tools, and observations through video recording.
- *Independent analysis* of work artifacts where already available and sometimes compiled data is used.
  - Examples: the case when documents such as requirements specifications and failure reports from an organization are analyzed or when data from organizational databases such as time accounting is analyzed.

Quantitative Data Analysis

- Data analysis is conducted differently for quantitative and qualitative data. For ***quantitative data***, the analysis typically includes analysis of descriptive statistics, correlation analysis, and hypothesis testing.
  - Descriptive statistics, such as mean values, standard deviations, histograms and scatter plots, are used to get an understanding of the data that has been collected.
  - Correlation analysis are conducted in order to describe how a measurement from a later process activity is related to an earlier process activity
  - Hypothesis testing is conducted in order to determine if there is a significant effect of one or several variables (independent variables) on one or several other variables (dependent variables).

Qualitative Data Analysis

- The basic objective of the ***qualitative analysis*** is to derive conclusions from the data, keeping a clear chain of evidence.

- The chain of evidence means that a reader should be able to follow the derivation of results and conclusions from the collected data.

- Analysis of qualitative research is characterized by having analysis carried out in parallel with the data collection since the approach is flexible and that new insights are found during the analysis.

- In order to investigate these insights, new data must often be collected, and instrumentation such as interview questionnaires must be updated.

Qualitative Data Analysis *(cont..)*

- In order to reduce bias by individual researchers in qualitative analysis, the analysis benefits from being conducted by multiple researchers.

- There are two different parts of data analysis of qualitative data
  - Hypothesis generating techniques intended to find hypotheses from the data.
  - Hypothesis confirmation techniques can be used to confirm that a hypothesis is really true.

Data analysis – Case Study Validity

- The validity of a study denotes the trustworthiness of the results, and to what extent the results are true and not biased by the researchers' subjective point of view.
  - Construct validity
  - Internal validity
  - External validity
  - Reliability

Construct Validity

- Construct validity is to w*hat extent the operational measures that are studied really represent what the researcher has in mind* and what is investigated according to the research questions
  - If the constructs (concepts) discussed in the interview questions are not interpreted in the same way by the researcher and the interviewed persons, there is a threat to construct validity.

Internal validity

- Internal validity *is of concern when causal relations (cause-and-effect) are* examined. When the researcher is investigating whether one factor affects an investigated factor there is a risk that the investigated factor is also affected by a third factor.
  - If the researcher is not aware of the third factor and/or does not know to what extent it affects the investigated factor, there is a threat to internal validity.
  - Thus, **internal validity** is only relevant in studies that try to establish a causal relationship.

External validity

- External validity is concerned with to *what extent it is possible to generalize the findings*, and to what extent the findings are of interest to other people outside the investigated case.

- In case studies, there is no population from which a statistically representative sample has been drawn.

- The intention is to enable analytical generalization where the results are extended to cases which have common characteristics and hence for which the findings are relevant, i.e., defining a theory.

Reliability

- Reliability is concerned with to *what extent the data and the analysis are dependent on the specific researchers*.
- Hypothetically, if another researcher later on conducted the same study, the result should be the same.
  - Threats to this aspect of validity are, for example, if it is not clear how to code collected data or if questionnaires or interview questions are unclear.

Case Study Reporting

Table 5.4 Proposed reporting structure for case studies based on Jedlitschka and Pfahl [86] and adaptations to case study reporting according to Runeson et al. [146]

Section headings	Subsections
Title	
Authorship	
Structured abstract	
Introduction	Problem statement
	Research objectives
	Context
Related work	Earlier studies
	Theory
Case study design	Research questions
	Case and subject selection
	Data collection procedure(s)
	Analysis procedure(s)
	Validity procedure(s)
Results	Case and subject descriptions, covering execution, analysis and interpretation issues
	Subsections, which may be structured e.g. according to coding scheme, each linking observations to conclusions
	Evaluation of validity
Conclusions and future work	Summary of findings
	Relation to existing evidence
	Impact / implications
	Limitations
	Future work
Acknowledgements	
References	
Appendices	

[86] Jedlitschka, A., Pfahl, D.: Reporting guidelines for controlled experiments in software engineering. In: Proceedings of the 4th International Symposium on Empirical Software Engineering, Noosa Heads, pp. 95–104 (2005)

[146] Runeson, P., H ¨ost, M., Rainer, A.W., Regnell, B.: Case Study Research in Software Engineering. Guidelines and Examples. Wiley, Hoboken (2012)

Example

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SPECIAL ISSUE PAPER

Effort estimation in agile software development: Case study and improvement framework

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Abstract

Abstract

Effort estimation is more challenging in an agile context, as instead of exerting strict control over changes in requirements, dynamism is embraced. Current practice relies on expert judgment, where the accuracy of estimates is sensitive to the expertise of practitioners and prone to bias. To improve the effectiveness of the effort estimation process, the goal of this research is to investigate and understand the estimation process with respect to its accuracy in the context of agile software development from the perspective of agile development teams. Using case study research, 2 observations and eleven interviews were conducted with 3 agile development teams at SAP SE, a German multinational software corporation. The results reveal that factors such as the developer's knowledge, experience, and the complexity and impact of changes on the underlying system affect the magnitude as well as estimation accuracy. Furthermore, there is a need for a tool that incorporates expert knowledge, enables explicit consideration of cost drivers by experts and visualizes this information to improve the effectiveness of the effort estimation. On the basis of the findings of the case study, a framework, inspired by the quality improvement paradigm is proposed to improve effort estimation in agile development.

Motivation

Most of the research on effort estimation in an agile context from real-world settings is based on a few surveys as described in Section 2. While this has helped to understand the broader state of the practice, there is value to be gained by conducting an in-depth analysis of this contemporary phenomenon in the agile context.

Contribution

Performing a case study with a case company in the,[6] we investigated why and how estimation is done and what factors are considered relevant for making estimates and for improving estimation accuracy.

Related Work

2 | RELATED WORK

A few secondary studies exist in the published literature that establish the state-of-the-art regarding different prospects of effort estimation in the context of agile development.

One secondary study[4] reviewed the literature on estimation in agile, iterative, and incremental projects. It concluded that there is a lack of research on finding the impact of properties of historical/current project data on estimation results. Furthermore, it has established that more empirical validation of estimation models is required.

Another secondary study[3] reviewed the literature on estimating effort in an agile context. The study concludes that the use of expert-based assessments is dominant and that there is lack of evidence on measuring prediction accuracy of proposed estimation techniques. It recommends considering factors other than size, for estimating effort.

A few surveys are also found in the published literature that investigated the state-of-the-practice regarding different perspectives of

Case Study Design and Execution

3 | RESEARCH STUDY DESIGN AND EXECUTION

3.1 | Objective and research questions

To achieve this objective, we designed and performed an exploratory case study at a German multinational software corporation, SAP SE. A case study is useful for gaining a deeper understanding of a specific phenomenon in its natural setting.[11] Table 1 shows the research questions along with their objectives that were investigated and are briefly listed below:

RQ1: How is effort estimation currently performed (purpose, process)?

RQ2: What factors are considered relevant and important for improving estimation accuracy? The flexible design of the study allowed us to include RQ3 after performing the observation sessions, ie.

RQ3: For which aspects of the effort estimation process do practitioners require tool support?

Case Study Design and Execution

3 | RESEARCH STUDY DESIGN AND EXECUTION

3.2 | Case study design

We chose a multiple-case design to get more in-depth insights on how estimation has been performed in agile software development. A multiple-case study is a variant that investigates at least 2 cases of the same phenomenon. Thus, it is especially useful for investigating a phenomenon across different settings and for exploring how the results vary among them.[12]

3.2.1 | Case study context

The case study was performed with a German multinational software corporation, SAP SE (Systems, Applications & Products in Data Processing). SAP SE develops enterprise applications in terms of software and software-related services to manage business operations and customer relations. Headquartered in Walldorf, Germany, SAP has its

Case Study Design and Execution

3 | RESEARCH STUDY DESIGN AND EXECUTION

3.2 | Case study design

3.2.2 | Case and unit of analysis

Studies on effort estimation show that Scrum and XP are found to be the most frequently-used agile methods for making estimates on the sprint or release planning level.[3,4] Therefore, we narrowed the context to the Scrum and XP methodology and defined the case to be studied as "Scrum and XP teams performing estimation while planning for a sprint". We intentionally selected the unit of analysis to allow the com-

TABLE 2 Unit of analysis

Characteristics	Team A	Team B	Team C
Team size	10	7	20
Team experience with software development (in years)	14	18	10
Team experience with agile development (in years)	4	4	5
Agile methods being used	Scrum, TDD, XP	Scrum, TDD	Scrum, TDD, XP
Programming language	ABAP	Javascript	Javascript

Case Study Design and Execution

3 | RESEARCH STUDY DESIGN AND EXECUTION

3.2 | Case study design

3.2.3 | Data collection

The first source driving the qualitative analysis was observations sessions of sprint planning meetings to watch the effort estimation process. The second source was a set of interviews. Data collection was

3.2.4 | Data analysis

Observations and interviews: We performed within-case and cross-case analyses. We first analyzed the data within each case (ie, in each team). Then, we compared, related, and integrated the results across the other cases (ie, across teams). Performing these analyses gave us opportunity to compare deviant cases with respect to estimation method (individual vs group estimation) and team size (small vs large). Qualitative data analysis was performed by using coding techniques and MAXQDA.[17] Coding here refers to the process of

Case Study Design and Execution

3 | RESEARCH STUDY DESIGN AND EXECUTION

3.3 | Threats to validity

Internal validity: To avoid bias in study results, only those teams were approached that had sufficient experience in agile methodologies. During the interviews, the practitioners were asked about their experience specifically in agile development in addition to their experience in software development in general.

External validity: As our case study used a convenient sample, our results might not be generalizable. However, they may be repeatable in a similar context and with similar characteristics with respect to agile development. To compensate for the small sample, we intend to design

Conclusion validity: To ensure reliability in the study execution, all steps of the study were performed by the same researchers,

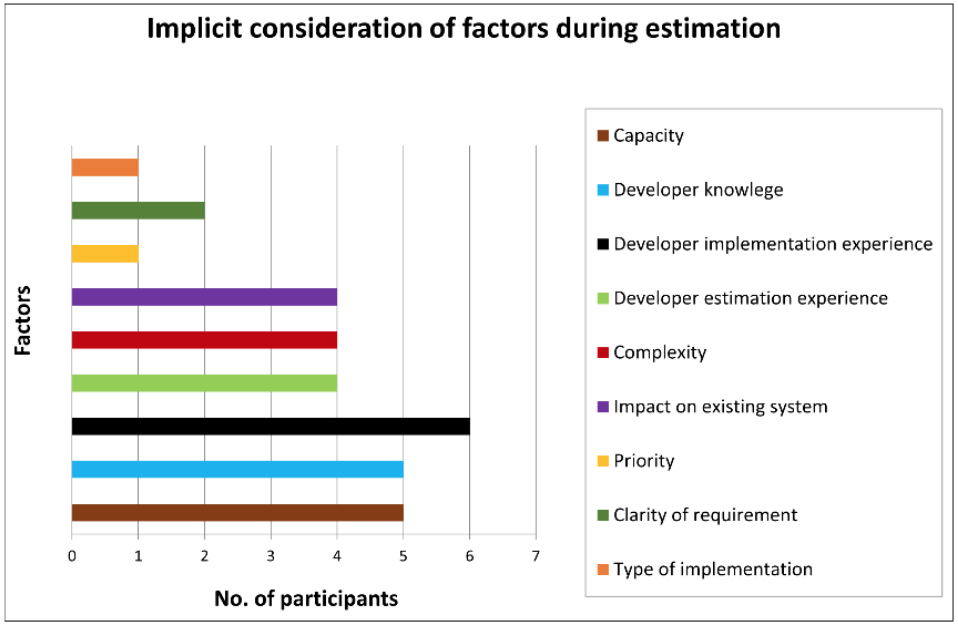
Case Study Results

4 | RESULTS

4.2 | Estimation accuracy factors

RQ2: What factors are considered relevant and important for improving estimation accuracy?

To investigate what factors are considered during estimation, we captured the interviewees' perspective in 3 different ways. First, the interviewees were asked in an open-ended question to provide factors they consider (implicitly in their minds) while making estimates.



Example 2

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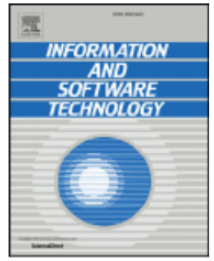

Effort estimation in large-scale software development: An industrial case study

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Summary

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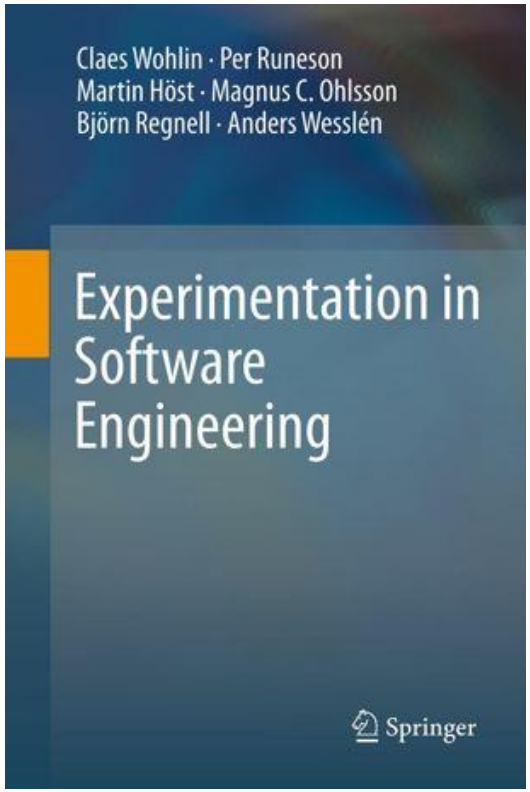
- The design of a case study and planning for data collection.
- The process of data collection.
- Issues on data analysis reporting

Reference



Chapter 5