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Documented decision-making strategies and decision knowledge in open source projects: An empirical study on Firefox issue reports

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ABSTRACT

Context: Decision-making is a vital task during software development. Typically, issue tracking systems are used to document decisions in large open source projects where developers are spread across the world. While most decision documentation approaches assume that developers use rational decision strategies, in practice also naturalistic strategies are employed. However, quantitative studies of the distribution of decision strategies and related knowledge are missing.

Objective: Our overall goal is to provide insights and ideas for further research to systematically support and document decision-making during software development in open source projects. In this paper, we analyze decisions documented in comments to issue reports in order to understand the documentation of decision-making in detail.

Method: We coded the comments of 260 issue reports of the open source project Firefox for decision-making strategies and knowledge on decisions. Then, we statistically analyzed the coded data with regard to the dominant decision strategy, the distribution of decision strategies and knowledge, and the relations between strategy and knowledge.

Results: The vast majority of documented decision-making strategies was naturalistic. Interestingly, for feature requests the percentage of rational decision-making strategies was higher than for bugs. Documented knowledge mostly concerned the decision context. More solutions were documented together with a higher amount of naturalistic decision-making. However, solutions were negatively correlated with the assessment of the situation. So, developers are likely to exploit and document decision problems and solutions in an imbalanced way.

Conclusion: Our analysis revealed important insights on how decision-making and its related knowledge is documented during software development in open source projects. For instance, we found naturalistic decision-making to play an important role for development decisions. Our coding tables can be used by other researchers to further investigate our results. The study insights should be reflected in decision support systems to improve their effectiveness and acceptance by developers.

1. Introduction

1.1. Research problem and goal

Decision-making is a vital task within the software engineering process [40], as the software system under construction depends on the decisions made during different development activities. In open source software projects, decisions are typically discussed and documented in issue tracking systems where *issue reports* are collected and processed during software development. For instance, Ko and Chilana [27] investigate decisions

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documented in issue tracking systems for the Firefox and the Linux kernel projects. Issues are reported by system users or developers to introduce and document a specific concern in the development. Then, the issue reports are discussed and processed by developers what may include further questions to the initial reporter. Issue reports can be divided into *bug reports*, which describe errors and unintended behavior, and *feature requests*, which describe functionality extensions. In most cases, issue reports indicate a specific need for adaption or improvement of a given software system. They may concern general system functions or only particular components. Thus, decisions made by the development team to address these needs are rather topical and often span across different development activities. When development teams are globally distributed and make issue-related decisions, for instance in the large open source project Firefox, they need a place to communicate and share their knowledge. Then, this knowledge is typically documented within the comments of an issue report.

Regarding the decision-making process, two major types of strategies can be distinguished: *rational decision-making* (RDM) and *naturalistic decision-making* (NDM) [56].

For developers, making decisions means to solve a decision problem by analyzing a set of alternatives with different criteria in order to choose a solution [35]. The criterion-guided analysis is a rational decision-making approach. Note that the common understanding is that developers should apply rational decision-making to identify the optimal solution for the given decision problem. For instance, RDM is encouraged for prioritizing requirements [4] or making architectural design decisions [13]. RDM basically means that all possible alternatives to solve the problem are carefully determined and examined by using a complete set of criteria. Therefore, all necessary information has to be collected by the developers. However, in practice, resource and time limitations impede developers in the complete collection and exploitation of information. Thus, a thorough application of RDM is often hindered.

Interviews with developers indicate that also naturalistic decision-making is applied in practice [56,57]. NDM is based on problem recognition and comparison between current and former situations to find an applicable solution in time. Therefore, solutions are used repeatedly for current decision problems, if these solutions have been successfully applied in similar situations before. In consequence, NDM is restricted by the decision makers' experience within the actual context and the knowledge of rules for recognizing and matching similar situations. We will refer to major aspects of these decision-making strategies, such as searching for an optimal solution or matching situations, as decision-making strategy *elements*.

Making a decision requires developers to collect and evaluate different kinds of knowledge on decision problems. In this paper, such knowledge is called *decision knowledge*. It consists of questions and context to describe the decision problem, alternatives to solve the problem and rationales to justify the choice [21]. We refer to these contents as decision knowledge *elements*.

The overall goal of this paper is described using the Goal Question Metric (GQM) approach [3]. It highlights the addressed matter, the investigated objects, the purpose of investigation, the study context, and the viewpoint from which the investigation is performed. Using GQM, the goal of our study can be formulated as:

- *Determine* significant quantitative effects
- *with respect to* documentation of decision-making strategies and their related knowledge
- *for the purpose of* improving the knowledge management
- *in the context of* development decisions in comments to issue reports for the open source project Firefox
- *from the viewpoint of* researchers.

The scope of our study is to investigate decision documentation without being restricted to a particular kind of decision-making process or decision knowledge. Therefore, we require access to a detailed documentation of decisions for large software development projects. Thus, we have chosen to investigate discussions in comments to issue reports of an open source project. Most open source projects, and Firefox in particular, do not enforce a specific documentation technique or style for decision knowledge (cf. study results of Ko and Chilana [27]), but offer a documentation of realistic and complex development activities and their related decisions. This documentation is *explicit* and *available* within issue tracking systems. The documentation is explicit, as development teams of huge open source projects usually are spread across the world. Therefore, they need to make their decisions and the corresponding discussion processes visible to the other team members on a common platform. The documentation is available, as typically open source projects try to encourage new developers to participate in the project. In consequence, all developers are interested in making the project and its decisions comprehensive and exploitable. Therefore, they share their current and previous decisions in issue tracking systems.

Current studies and documentation approaches typically address specific kinds of decisions (cf. Section 2), such as decisions on architecture and design. We identified two important characteristics within this existing work. First, existing studies either focus on observing the developers' decision-making behavior [45] or perform interviews to examine decisions in retrospect [56,57]. In consequence, many existing studies do not provide quantitative results for decision-making. Second, decision knowledge is often investigated in relation to given knowledge models (cf. [8,29,31,52]) and their tool support (cf. [28,48]). Also, links between decisions and related artifacts like requirement specifications [1,5], architecture descriptions [22,58], or code files [7,20] are investigated. All these approaches address software development projects in general and are typically applied in academic example projects or well-defined industry case studies. In consequence, developers are typically requested to apply a particular style of documentation [32], or they are biased by other project-specific documentation constraints. In addition, access to realistic and detailed data with different development iterations and multiple developers is limited.

Regarding these characteristics, our study complements the insights from existing studies by performing a quantitative analysis of decision documentation in issue tracking systems of an open source project. We expect that our study also provides general insights for software development in open source projects, which should be subject to further research. However, it is important to note that the study does not aim at assessing the quality or outcome of a decision. Moreover, we only cover documented decision-making strategies and decision knowledge. When developers think about making a decision, they may follow one strategy and document their thinking according to another one. For instance, the outcome of a developers rational weighing of different alternatives could result in a naturalistic documentation favoring one solution and omitting the process behind this claim. However, for other developers, only the documentation of this decision process is available and therefore crucial for their comprehension. Therefore, our approach is only focused on decision documentation and our analyses and results only apply to documented decision-making strategies and knowledge.

1.2. Research questions and contributions

We address the aforementioned goal by investigating three different research questions that are outlined in the following paragraphs.