FOCUS AREAS, THEMES, AND OBJECTIVES OF NON-FUNCTIONAL REQUIREMENTS IN DevOps: A SYSTEMATIC MAPPING STUDY

TECHNICAL REPORT

Philipp Haindl$^{1,2}$ and Reinhold Plösch$^2$

$^1$Software Competence Center Hagenberg, Austria
$^2$Department of Business Informatics - Software Engineering, Johannes Kepler University Linz, Austria

ABSTRACT

Context: Software non-functional requirements address a multitude of objectives, expectations, and even liabilities that must be considered during development and operation. Typically, these non-functional requirements originate from different domains and their concrete scope, notion, and demarcation to functional requirements is often ambiguous. **Objective:** In this study we seek to categorize and analyze relevant work related to software engineering in a DevOps context in order to clarify the different focus areas, themes, and objectives underlying non-functional requirements and also to identify future research directions in this field. **Method:** We conducted a systematic mapping study, including 142 selected primary studies, extracted the focus areas, and synthesized the themes and objectives of the described NFRs. In order to examine non-engineering-focused studies related to non-functional requirements in DevOps, we conducted a backward snowballing step and additionally included 17 primary studies. **Results:** Our analysis revealed 7 recurrent focus areas and 41 themes that characterize NFRs in DevOps, along with typical objectives for these themes. Overall, the focus areas and themes of NFRs in DevOps are very diverse and reflect the different perspectives required to align software engineering with technical quality, business, compliance, and organizational considerations. **Conclusion:** The lack of methodological support for specifying, measuring, and evaluating fulfillment of these NFRs in DevOps-driven projects offers ample opportunities for future research in this field. Particularly, there is a need for empirically validated approaches for operationalizing non-engineering-focused objectives of software.

Keywords Non-functional Requirements · Software Quality Attributes · DevOps

Remark

This paper is an addition to our peer-reviewed publication in [1] and contains a more elaborate presentation of our findings. When citing our work, please always cite the peer-reviewed publication; citing this technical report should always be optional for cases where you explicitly reference aspects that were not published in the peer-reviewed publication.

1 Introduction

The common notion of non-functional requirements (NFRs) of software, such as e.g., maintainability or performance efficiency, primarily targets **engineering-focused** objectives of software. As such they disregard the also **non-engineering-focused** objectives pursued with software, e.g., that it is frequently used by customers, generates revenue aligned with the business model, and that its monitored usage data allows to ideate new features for the customers. Due to the lack of awareness for these non-engineering-focused NFRs, they are often only vaguely elicited and balanced with functional requirements [2, 3, 4, 5]. This in turn disguises business, staffing, and organizational considerations that
also have an impact on decisions in software projects. Also, it makes it difficult for software engineers to appropriately react to deviations of these NFRs in DevOps. Due to the absence of a comprehensive classification scheme that takes into account the heterogeneity of domains having an impact on NFRs, it is cumbersome to properly approach them in software specification documents and meet the different stakeholders’ objectives. As an example, the objectives towards exchangeability of software developers or transaction-cost monitoring in DevOps exceed the primarily engineering-focused understanding of NFRs. These cases of NFRs are primarily applicable in DevOps as they require a thorough indentation between the development and operation perspective of software.

Specifically the evolution of BizDevOps \[6,7\] emphasizes the necessity for authors to more intensively integrate business and other non-engineering-focused NFRs in the DevOps context. Several works have stressed the required alignment between business processes, strategic objectives, company culture, and engineering decisions with DevOps \[8,9,10,11\]. In addition, the ubiquity and volume of data accruing in DevOps provide ample methods for evaluating fulfillment of NFRs to continuously improve the software. The absence of a classification scheme for NFRs in DevOps and the thereof pursued objectives also hinder the effective formulation of respective measures that can then be acquired and assessed in the DevOps cycle.

1.1 Problem statement and motivation

To increase the value of DevOps in practice and assure a better alignment with non-engineering-focused objectives in software projects, a comprehensive classification of NFRs, typical themes, pursued objectives and implementation practices in DevOps is required. In order to examine the handling of NFRs in DevOps we conducted a systematic mapping study in combination with backward snowballing that included 142 primary studies. The following paper presents the findings from this mapping study.

The focus of this research was on examining

- which NFRs are relevant and typically handled in DevOps, and
- how these NFRs can be classified by focus areas and subordinate themes, and
- what objectives are pursued with these NFRs;

We also analyzed the publication channels, contributions and research facets as well as the frequency distribution over the years. In order to get a solid understanding of the current state of practice of NFRs in DevOps, we followed a snowballing procedure and selected further relevant papers for inclusion in our analysis. In the context of this paper we refer to DevOps as \"a set of practices intended to reduce the time between committing a change to a system and the change being placed into normal production while ensuring quality\" \[12\]. The introduction and practice of DevOps shall however not be seen as an isolated software engineering activity, but also requires organizational changes. In many cases this organizational change is much more fundamental than the changes in the software engineering process, as it additionally requires significant adaption to other processes, e.g., change management processes \[13\].

Our work seeks to augment the common understanding of NFRs by contributing new facets about the different scopes and objectives behind NFRs, specially in DevOps. The different perception and understanding of NFRs also becomes apparent when skimming the definitions of NFRs from other publications. In one of the first publications in this domain \[14\], economic aspects of software are mentioned in the same turn as purely engineering-related aspects such as reliability, usability or safety. Other authors \[15,16,17\] reflect only on the structural and behavioral aspects of NFRs and hence also approach them solely from a technical perspective. In contrast, recent works in this context \[18,19\] have a broader notion of NFRs. These works stress that also "...environmental factors, such as legislation related to the business branch and compliance, may introduce vital requirements..." and that "...user needs and other stakeholders should not be forgotten, either.\". To summarize, there still is no clear demarcation between functional and non-functional requirements \[20,16\] and how to approach and evaluate non-engineering-focused NFRs that affect the design, implementation, and operation of software.

1.2 Contribution

Our study shows that there are multiple perspectives on why and how to approach NFRs in DevOps. These perspectives are reflected by different points of focus that are typically (and often tacitly) taken in software projects and range from engineering-related qualities, e.g., static or dynamic code analysis, to non-engineering-related qualities addressing business, legal, or organizational requirements. As an example, these requirements address how to balance economic requirements of the software, the mapping of software artefacts and their contribution to revenue streams, or motivational factors influencing the development and operation of software.
Resulting from our analysis of 142 relevant papers in this systematic mapping study, we contribute an analysis and thematic classification of the current state of research in this field. The analysis of the studies takes into account the research and contribution facets, publication channels, and the publication frequency of the studies over time. Complementary, the NFRs in DevOps described in the studies are classified by focus area, typical themes, and pursued objectives. In particular, our work seeks to extend the primarily engineering-focused understanding of NFRs by showing their heterogeneity in the analyzed studies and their relevance specially in DevOps.

1.3 Outline

The remainder of the paper is organized as follows: In Section 2 we provide an overview of work related to our study. Section 3 presents the research methodology, introducing the research goals and questions and how each method has been applied in this literature study. The analysis of the study population showing the different facets of the studies, publication channels, and the publication frequency over time is elaborated in Section 4. Following, the focus areas of NFRs in DevOps are presented in Section 5 before the themes and objectives related to these NFR focus areas in DevOps are portrayed in Section 6. The findings from our study are discussed in Section 7, followed by outlining the threats to the validity of our results in Section 8. Finally, we conclude our paper in Section 9 and attach the details of the used classification schema in A and the systematic map of all analyzed primary studies in B.

2 Related work

In this section we elaborate on related work in the context of handling NFRs in DevOps, the necessity for this study and how we demarcate our work from other authors. Basically, 3 streams of research can be identified:

The first stream of related research deals with the scope and notion of NFRs towards software. Particularly, this tackles the question where to draw the demarcation between non-functional and functional requirements and whether the notion of NFRs also covers non-engineering-related concerns, e.g., business, organizational or legal concerns. These concerns also affect the design, development, and operation of the software [20, 3, 16] and may also become manifest in NFRs. The differentiation between non-functional and functional requirements is not only prevalent in research, but also affects the elicitation, documentation, and validation of NFRs in software projects. Eckhardt et al. [17] analyzed 530 NFRs of 11 industrial requirements specifications regarding the extent these NFRs describe system behavior. They concluded that most many so-called NFRs actually are not non-functional, but instead could be treated as functional requirements. However, the focus of the analyzed NFRs is primarily engineering-oriented and leaves out non-engineering-related concerns which may also become manifest in NFRs. The differentiation between non-functional and functional requirements is not only prevalent in research, but also affects the elicitation, documentation, and validation of NFRs in software projects. Mairiza et al. [21] examined 182 sources of information elaborating NFRs, ranging from academic articles to technical reports and white papers, and categorized them depending on their type of being either business, external, development or quality related. For each extracted NFR from these sources, they analyzed whether it adheres to a common definition, has concrete measurable attributes and a concrete measurement methodology defined for it. They concluded that only around 20% of NFRs typically arising in software projects are commonly defined covering attributes and measurement methodology. The remaining 26% of NFRs at least have a definition, but for the majority of over 53% of common NFRs neither their attributes nor their measurement methodology is defined, leaving them factually ignored in the development process. Also, the authors of this work conclude that the common notion of NFRs leaves out important non-engineering-related aspects that have an impact specially on the development of the software and specifically, that further research addressing scope, notion, and measurement of NFRs shall be done.

The second stream of relevant works comprises systematic literature reviews and mapping studies. Hasan et al. [22] argue that NFRs are often ignored, inadequately specified, and rarely treated as first-class elements such as functional requirements. In the frame of a systematic literature review (SLR) the authors analyzed 92 describing approaches for handling NFRs in the software development lifecycle, to examine the documentation approaches and scopes of NFRs in software projects. The focus of their work is not on the scope of NFRs itself, but primarily on approaches for their elicitation, documentation, and handling. The authors categorize these approaches into goal-, aspect-, or pattern-oriented NFR elicitation approaches. While goal-oriented NFR elicitation techniques result in higher preciseness and less ambiguity of the NFR specification, the authors also stress that the plethora of NFR elicitation techniques is due to the lack of a thorough taxonomy for NFRs. They also underline that despite the undisputed advantages of these techniques, most of them can only be used by domain experts, which complicates NFR elicitation and specification in software projects. Ouhbi et al. [23] performed a systematic mapping study based on 51 primary studies, mainly to analyze the population of studies dealing with software quality elicitation and specification. In their study, the authors solely take into account NFRs that adhere to the ISO/IEC 25010 specification. Their study summarizes that NFRs are mainly validated during development and that data from software operation are often disregarded or not used effectively.
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for NFR validation. Also, the authors conclude that there is a need for more studies focusing on the validation of NFRs throughout the development lifecycle.

The last stream of relevant research examines the handling of NFRs in the DevOps context. In a qualitative multiple-case study, Ruungu-Kalliosaari et al. [24] interviewed practitioners about the challenges and benefits of DevOps adoption. In the interviews, the respondents mentioned that NFRs in DevOps primarily focus on product quality, thus neglecting the quality of the software development, delivery, and operation process. This aligns with the work of Senapathi et al. [9] who conducted an exploratory case study interviewing several software engineers to explore the challenges linked with adopting DevOps practices. In the interviews, the experts responded that in practice they are confronted with non-engineering-focused NFRs such as e.g., the alignment of the software with revenue streams or feature ideation from monitored user behavior. These non-engineering-focused NFRs are not fully covered by the primarily engineering-oriented notion of NFRs and hence are often neglected in DevOps. Though, similar to engineering-focused NFRs such as e.g., maintainability of the source code, they have a direct effect on whether the objectives pursued with software can be fulfilled and with what efforts and costs.

It can be summarized that multiple related works stress the solely technical notion of NFRs and suggest to rethink their scope to more effectively specify, measure, and evaluate non-engineering-focused NFRs, e.g., business, organizational, human, and legal requirements. Particularly in DevOps with a multitude of data originating from different systems, a thorough catalogue of NFRs along with their focus, typical themes, subordinate objectives, and measures is the prerequisite for more effectively approaching NFRs. The presented systematic mapping study aims to close this gap through providing a detailed classification of NFRs in DevOps – by focus areas, themes, and pursued objectives.

3 Research methodology

The research presented in this paper resulted from a systematic mapping study conducted over the period of 9 months (December 2018 to August 2019). There is an important distinction between systematic literature reviews and mapping studies: Systematic literature reviews (SLRs) intend to “identify best practice with respect to specific procedures, technologies, methods or tools by aggregating information from comparative studies” while the result of a systematic mapping studies is a “classification and thematic analysis literature on a software engineering topic” [25]. As already outlined in Section 2, the notion and scope of NFRs still remain vague in academic works and industry, specifically whether non-engineering-focused concerns are also covered by this term. Therefore, in our mapping study we augmented the set of analyzed papers through a snowballing procedure [26] to also capture primary studies that elaborate on non-engineering-focused NFRs in DevOps. For the sake of transparency and reproducibility of our study, we aimed to keep the number of additionally included papers small.

3.1 Research goal and questions

The overall research goal for this study can be described through the following objectives: to (a) analyze the publication population in this field and particularly the research and contribution facets; (b) provide a comprehensive catalogue of engineering- as well as non-engineering-focused NFRs; (c) nurture a broader understanding of the different focus areas, themes, and subordinate objectives of NFRs in DevOps; and (d) outline directions for future research. Below we present the research questions that were derived from these objectives.

• What is the current state of research pertaining to NFRs in the context of DevOps? (RQ1)

  We took common bibliometric perspectives onto the current state of research pertaining to this field and refined them into corresponding research questions.

  – What is the distribution of research facets in studies related to NFRs in DevOps? (RQ1.1)
  – What is the distribution of contribution facets in these studies? (RQ1.2)
  – What are the publication channels and venues used to publish related studies? (RQ1.3)
  – How did the publication frequency of related studies evolve over time? (RQ1.4)

  In RQ1.1 and RQ1.2 the perspectives are on the research and contribution facets of the works respectively. Complementary, RQ1.3 examines the typical publication channels and venues of works in the field of NFRs in DevOps. The analysis of the respective publication population is finally supplemented by RQ1.4, which investigates how the publication frequency of the studies evolved over time.

• How can NFRs typically relevant in the context of DevOps be characterized? (RQ2)
The focus of RQ2 is on carving out which NFRs can be discovered recurrently among the different studies and are typically important in DevOps. Therefore, the NFRs described in the studies are categorized by their conjoint focus area, i.e., their spanning characteristics and objectives.

- **Which themes and objectives are associated with each focus area of NFRs in DevOps? (RQ3)**

  This question analyzes representative themes and objectives that are pursued with each NFR focus area. If possible, we present them along with tangible practical examples and associated challenges.

Based on these research questions we defined the data to be extracted from the primary studies (cf. Section 3.6).

### 3.2 Research process and steps

The overall research design of our mapping study is depicted in Figure 1. We followed the process as suggested by Petersen et al. [27] but extended it by a snowballing step (step 4, Figure 1). The process itself was iterative and we repeated individual steps the more we learned about the data available in the primary studies and how we could integrate them in our study. Also, we refined the research questions with increasing knowledge about NFRs, DevOps, and the challenges that are associated with the combination of these two topics.

Below we describe the design and execution of the systematic mapping study in a sequential manner: The need for the study emerged from our related activities in this field [28, 29] pertaining to the extension of an operational software quality model to evaluate the fulfillment of NFRs on the level of software features, particularly in DevOps. The research questions (step 1, Figure 1) are elaborated in Section 3.1. They define the concrete review scope of the systematic mapping study. Accordingly, the review scope also influences the search string used to retrieve representative papers for the topic of interest. We piloted the search string several times until we ended up with a clear definition of it, which repeatedly returned the most stable and complete set of relevant papers for this topic.

Consequently, we searched for publications on selected databases (cf. Section 3.3) using predefined search strings (step 2, Figure 1) following the PICO schema [30]. The concrete search strategy, the database-dependent search strings, and the rationales behind the composites of the search strings are described in Section 3.3. From all papers we excluded duplicate, unrelated, and non-English works upfront (exclusion criteria 1-2). Then we screened these candidate papers thoroughly (step 3, Figure 1) and again selected only papers according to the predefined inclusion and exclusion criteria (tentative papers). The applied inclusion and exclusion criteria are detailed in Section 3.4.

Several authors emphasize that the scope and notion of NFRs are still vague in academic literature [20, 3, 16]. To address this limitation and to capture further papers contributing to a broader notion of NFRs, we subjected the tentative papers (step 3, Figure 1) a backward-snowballing procedure and included selected cited papers (step 4, Figure 1) into the final paper set (relevant papers) for this mapping study. The snowballing procedure [26] is elaborated in Section 3.5. Consequently, we extracted recurrent keywords and key themes from the abstracts of the papers to develop and repeatedly refined our classification schema (step 5, Figure 1). Resulting from this step is a classification scheme that particularly regards the focus areas of NFRs in DevOps, which is the prerequisite for the systematic map as one outcome of the mapping study. Then we analyzed all papers to gain a thorough understanding about these NFRs (step 6, Figure 1) to synthesize the focus areas, themes, and objectives associated with NFRs in DevOps. In the last step we used the classification scheme to extract the metadata, map the papers according to predefined characteristics, e.g., research and...
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| Search term | Rationale |
|-------------|-----------|
| Population  | *DevOps   | Studies discussing DevOps principles and practices. The wildcard operator is used to also match related terms, e.g., in the context of "BizDevOps". |
| Intervention| qualit*    | Studies discussing quality in the context of DevOps (e.g., "quality", "qualities"). |
| OR          | non-functional* | Studies discussing non-functional requirements and similar terms in the context of DevOps (e.g., "non-functional attributes", "non-functional requirements", "non-functional concerns"). |
| OR          | NFR*      | Studies discussing non-functional requirements using the abbreviation "NFR". |

Table 1: Population, intervention, and search string keywords.

During the pilot study we also discovered that though most works share the common technical notion of NFRs, an ample amount of works elaborates on non-engineering-focused NFRs. These works intensively contribute to a broader understanding of NFRs and their objectives in general, which was also described in Section 1.1 as research motivation for conducting this study. When analyzing the references of these papers, we also noticed that they often referred to other relevant papers contributing to a better understanding of the different types of NFRs. Thus, we decided to subject these primary studies to a snowballing procedure as described in Section 3.5 and include their backward references if they meet the defined inclusion requirements.

The databases for searching the primary studies were selected considering their coverage of the software engineering literature and are shown along with the respective search string, filter, and retrieved paper count in Table 2. In order to regard the individual syntax of each database and assure we retrieve the complete set of relevant works from each database, we adapted the search string accordingly.

Whenever possible we also defined filters to narrow the result set according to the primary study selection criteria described in Section 3.4. We did not utilize an additional time filter as we were interested in the full time spectrum of the studies. The top-right column of the table shows the number of retrieved papers from each database, totaling to 229 papers (up to and including July 2019).

3.4 Primary study selection criteria

In Figure 1 we illustrate the screening procedure, the numbers of retrieved papers from each database, and the numbers of included and excluded papers during study selection. The selection of the primary studies was performed by the two co-authors with one researcher checking the retrieved 229 primary studies prior to the screening (step 2, Figure 1). This initial review comprised only title, author, and publication channel of the papers. Inappropriate or duplicate
papers were excluded upfront, resulting in 70 of the 229 studies being excluded. To mitigate study selection bias, we discussed disagreements of upfront excluded papers until consensus was reached. Consequently, the remaining 159 primary studies were reviewed by both researchers against predefined inclusion/exclusion criteria (step 3, Figure 1). Both researchers reviewed all studies individually, resulting in 23 disagreements regarding the selection of these studies. Again, we discussed the selection of these studies in detail until we agreed on a final set for the selection. Below we outline the applied inclusion and exclusion criteria.

### Inclusion criteria:

1. Elicitation, specification, operationalization, and monitoring of NFRs in DevOps
2. Fulfillment evaluation of NFRs or quality aspects in DevOps
3. Different engineering strategies and their effect on software quality and NFRs in DevOps
4. The integration of technical and business objectives and their handling in DevOps
5. Benefits, challenges, and limitations of DevOps and their effect on software quality

### Exclusion criteria:

1. Duplicate articles
2. Works not written in English
3. PhD or Master Theses
4. Technical reports or white papers
5. Works that not clearly discuss DevOps and NFRs in the frame of software engineering

Though they are not peer-reviewed works, we also included books and book chapters retrieved from the academic databases in the initial screening. However, we only regarded these works if they could be attributed to the common body of knowledge or have at least one author with a strong and traceable academic record. In total we excluded 44 primary studies, the majority of the excluded papers being too generic or non-relevant to the studied topic. Our review resulted in 115 primary studies being selected for the subsequent snowballing procedure. Finally, we included additional 27 publications (of which 13 are books and book chapters) referenced by the 115 primary studies, which totals to 142 publications finally selected for the mapping study.

### 3.5 Snowballing procedure

As we discovered that also the references retrieved through the systematic search contain valuable information for understanding the notion and scope of NFRs, we decided to also include a backward snowballing procedure. For the sake of transparency and repeatability of our study, we paid attention on the number of papers added through
snowballing. Overall, we strived to keeping the number of thereby added papers as little as possible, but also as extensive as necessary to contribute to a broader notion specially of non-engineering-focused NFRs in DevOps.

The snowballing procedure was done by two researchers conjointly, with each one reviewing each paper separately and deciding about the further handling of each paper again conjointly. If there were differences about how to proceed with a paper, we repeated the analysis of the respective paper and discussed until consensus was reached.

We followed the process as outlined by Wohlin [26] and selected the 115 papers remaining after exclusion based on abstract, introduction, or conclusion (cf. Figure 1) as the tentative start set for the snowballing procedure. Thus, this set originated from the structured search on 5 academic databases and the inclusion and exclusion of papers adhered to concrete and predefined criteria described in the previous section. In total, we conducted 4 iterations of the snowballing process and thereby analyzed each paper in its entirety and not only selected parts of it. The reason for that being to evaluate if the NFRs described in an analyzed paper do require additional complementary information, such as most likely in the case of non-engineering-focused NFRs, or if the described NFRs rather fit to the common and technical notion of NFRs, thus not requiring any further elaboration.

As suggested by Wohlin [26], when deciding whether to include a referenced paper, we specially regarded the place and context in which it was cited in the original paper, as this might give additional hints about its focus. After selecting a referenced paper as a candidate for inclusion, we studied it in detail and evaluated, whether it actually contributes to broadening the notion of NFRs in DevOps. Specifically, we examined which properties (cf. Table 3, P5-P7) we can extract from a study and thus how it could contribute to answering the research questions more thoroughly. We only included papers of which we could extract at least two properties. Contrarily, we excluded all papers from being further regarded in the snowballing process if they were either too generic regarding their NFRs scope, did not provide new insights into this topic, or because they solely elaborated on basic common knowledge. Also, we recorded which papers we have already examined and the rationale for either inclusion or exclusion from snowballing.

Starting with the set of papers retrieved from the structured search we conducted the backward snowballing process 4 times, resulting in the following statistics:

- **Start set:** Out of the references of 115 papers originating from the structured literature search, we selected 38 candidates of which 9 papers were included, i.e., efficiency = 9/38 = 23.7%.

- **Iteration 1:** 26 candidates originating from snowballing from start set and 7 papers were included, i.e., efficiency = 7/26 = 22.2%.

- **Iteration 2:** 35 candidates originating from snowballing from iteration 1 and 9 papers were included, i.e., efficiency = 9/35 = 25.7%.

- **Iteration 3:** 12 candidates originating from snowballing from iteration 2 and 2 papers were included, i.e., efficiency = 2/12 = 16.7%.

- **Iteration 4:** 15 candidates were examined from iteration 3, but no papers were further included, i.e., efficiency equals to 0%.

We stopped the snowballing procedure after 4 iterations as we did not find any further papers being relevant for inclusion in the final set. The overall efficiency of our snowballing procedure, that is calculated on all candidates, equals to (9+7+9+4+2+0)/(38+26+35+12+15) = 27/126 = 21.4%. During the snowballing process we also noticed that each candidate paper must be analyzed thoroughly, as an analysis spanning just the title and abstract might often be misleading. Also, we observed that the additional snowballing procedure in many cases led to relevant papers of other domains being included, e.g., from the business, product and strategic management domain, which we would not have without this step. It shall be noted that actually those papers helped us gaining a better understanding about the scope and notion, particularly, of non-engineering-focused NFRs in the software lifecycle.

### 3.6 Data extraction

In the next step, we extracted the predefined properties shown in Table 3 from each selected primary study. This task was done by each researcher separately using a tool\(^1\) for qualitative text analysis. Overall, we extracted 2 categories of data that also map with the research questions: properties P1-P5 focus on the analysis of the publication population, properties P6-P8 capture the overall focus, themes, and objectives of the NFRs described in a primary study.

In the following we describe the data extraction for each property from the primary studies.

\(^1\)MAXQDA Plus, https://www.maxqda.com/
3.6.1 Primary study properties (P1–P5):

We extracted 4 properties for answering RQ1.1-RQ1.4, which are briefly described below. The detailed description of the classification schemes and these properties is given in Table 12.

1. **Research facet (P1):** Categorizes the studies by applied research design, i.e., how the statements presented in the studies have been evaluated. We used existing classification schemes [31, 27] and distinguished between experience reports, evaluation/validation research, philosophical/opinion papers, and solution proposals.

2. **Contribution facet (P2):** Maps the different outcomes of the studies. Again, we followed existing classification schemes [32, 33] and defined 6 categories: model, method, theory, framework, guideline, and lessons learned.

3. **Publication channel (P3), venue (P4), and year (P5):** Captures the publication channels, venues, and years of the studies.

3.6.2 Focus areas, themes, and objectives of NFRs in DevOps (P6–P8):

To examine the focus areas and objectives associated with NFRs in DevOps, we extracted 3 properties from the studies which help answering RQ2 and RQ3.

1. **General focus area of NFRs in DevOps (P6):** Summarizes the general focus of NFRs in DevOps described in the studies. To facilitate the inductive coding necessary to capture the qualitative nature of this property, we setup 7 different focus areas of NFRs ab initio: customer, development, operation, governance, quality, organization, and business. An elaborate definition of these focus areas is given in Table 13. We derived these focus areas from our pilot study when developing the search strings (cf. Section 3.2) and encountered them recurrently among these papers.

2. **Themes (P7) and objectives (P8) associated with focus areas of NFRs in DevOps:** We introduced the concept “objectives” to capture the underlying goals and motivations tacitly associated with NFRs in DevOps and grouped them by spanning theme. In most studies, these objectives are either expressed vaguely, outside the research scope of the study, or not clearly distinguished from functional requirements [16]. If the objective was clearly stated in a study, we codified the respective statements. Otherwise we codified the origin and context that an NFR was mentioned in or the stakeholder(s) who explicated an NFR.

| ID | Property                                           | Research question |
|----|----------------------------------------------------|-------------------|
| P1 | Research facet                                     | RQ1.1             |
| P2 | Contribution facet                                 | RQ1.2             |
| P3 | Publication channel                                | RQ1.3             |
| P4 | Publication venue                                 | RQ1.4             |
| P5 | Publication year                                   | RQ1.4             |
| P6 | Focus area of NFRs in DevOps                      | RQ2               |
| P7 | Themes associated with NFR focus area in DevOps    | RQ3               |
| P8 | Objectives associated with theme of NFR focus area | RQ4               |

Table 3: Data extraction form.

3.7 Data analysis and interpretation

We used descriptive statistics to analyze the data relating to RQ1.1-RQ1.4. Particularly, we analyzed these data regarding the frequencies of research and contribution facets, publication channels, and years. In addition, we used logarithmic regression for trend analysis of the publication years. The analysis of the respective data was done by two researchers separately.

For analyzing the qualitative data relating to RQ2 we used thematic synthesis [34]. The classification schema for analyzing the extracted properties was derived from the pilot study during developing the search strings (cf. Section 3.2). Thus, this classification scheme was available right at the beginning of the data analysis and not developed iteratively. We solely used inductive coding for analyzing the data of this research question. The main objective of this analysis was to match the codings, which marked the relevant passages in the text of the studies, to the given NFR focus areas. We however revised this classification schema regularly to assure that the labeling of the NFR focus areas suitably describe the related studies. The analysis of the studies according to the given classification schema was done by two researchers separately, followed by a final review of this classification by all researchers conjointly.
In contrast, for analyzing the data related to RQ3 to identify the themes and objectives associated with NFRs in DevOps, we used inductive and deductive coding. First, we labelled the relevant text fragments in the studies using an inductive approach and derived descriptive codes on the level of individual studies. Then, after labelling all studies this manner, we iteratively derived more generic codes that span and suitably describe the more specific codes. For example, we encountered text fragments in the studies that reflect on the use of certain versions of libraries, compare advantages of certain frameworks or elaborate on specific programming patterns to assure compatibility with a framework. In this case we synthesized these text fragments through the code \textit{framework compliance}. After we had developed an initial list of codes, we revised each code to check whether it suitably matches the content of the associated study and also that it doesn’t leave out important semantic subtleties of the encoded text fragments. When reviewing this initial list of codes, we iteratively refined codes and reviewed if the new codes better fit to the referred text fragments. We repeated this step multiple times until we finally agreed upon a consolidated list of codes.

Specifically, when extracting the themes and objectives described in the studies, we noticed that many studies cannot be attributed to a single focus area. Instead, they describe multiple focus areas, themes and thus also different objectives underlying NFRs in DevOps. In these cases, if relevant for answering the research questions, we separately encoded all described focus areas, themes, and objectives in a single study.

4 Overview of the state-state-of-the-art: NFRs in DevOps (RQ1)

After reviewing 229 primary studies retrieved from the academic databases (cf. Figure 1) and an additional snowballing step, we selected 142 primary studies for this mapping study. In this section we present our findings from examining the bibliometrics of the study population, such as the research and contribution facets, used publication channels and publication frequency using descriptive statistics. The primary studies were classified according to the classification schemes, as defined in A, Tables 12 and 13. While in this section we present our summarized findings, the details how we categorized each primary study according to these facets are elaborated in B, Table 14.

4.1 Research facets (RQ1.1)

Most primary studies on the state-of-the-art handling of NFRs in DevOps present practical solutions or experiences (63%, comprising evaluation/validation research, experience reports, and solution proposals), contrasted by 37% of studies being solely theoretical (represented through philosophical/opinion papers and solution proposals) expressing the personal opinion of the authors and without claiming practical applicability. Figure 2 shows the distribution of the 6 research facets. Interestingly, only 8% of primary studies share practical experiences regarding handling NFRs in DevOps. An innovative contribution to this research area can primarily be found by 29% of the studies, contributed through philosophical papers and solution proposals. Contrarily to these both types of works, opinion papers having a share of 17% of the studies do not rely on related work or any sound research methodology and thus also do not claim for applicability, feasibility or suitability of the presented ideas.

![Figure 2: Distribution of research facets.](image)

To summarize, practically applicable and empirically validated approaches for handling NFRs in DevOps only constituted 19% of the primary studies, represented by the studies based on evaluation research. The remaining studies either are not empirically validated, solely theoretical, or primarily innovate without any form of structured validation.
4.2 Contribution facets (RQ1.2)

In Figure 3 we show the distribution of the contribution facets of the studies. Many studies contributed to the theory of NFRs in DevOps (26%, e.g., requirements prioritization criteria [35], share experiences and lessons learned in practice (17%) such as the capabilities and challenges of DevOps faced in industrial settings [9], or describe general advices for handling NFRs in DevOps (10%), such as the organizational change associated with DevOps adoption [36]. On the other side, 40% of the studies contribute concrete approaches, comprised of methods (17%) (e.g., for evaluating the fulfillment of NFRs towards value streams [37], frameworks (11%), (e.g., for guiding the evaluation of NFRs specially in DevOps [38]), models (9%) e.g., for feature ideation from user interactions [39], and tools (3%) for instance to support customer value estimation during feature ideation [40].

Processes for handling NFRs in DevOps are contributed by only 1% of the studies. It can be summarized that the emphasis of the studies in this field is on theoretical and conceptual contributions (60%, comprised of 17% reports about lessons learned, 6% guidelines, 26% theoretical analyses, 10% advices and 1% presenting processes).

4.3 Publication channels and venues (RQ1.3)

We also analyzed which channels are used for publishing the studies and illustrate this distribution in Figure 4. The smallest share of studies dealing with the handling of NFRs in DevOps is published in books (as chapters), comprising only 11% of all studies. The remaining 89% of studies are either published on scientific conferences (44%) or journals (45%), which typically follow a stricter review process than conferences. While the dominance of journal publications is not a valid measure of the quality of the studies, it might be an indicator of high research efforts spent in this field.
4.4 Publication frequency over years (RQ1.4)

As the final step of the quantitative description of the study population, we also analyzed the number of publications per year. As depicted in Figure 5, the reviewed studies were published between 1998 and 2018. The figure also shows the steady incline in publication over the years, illustrated through the dotted regression line.

Although the first 12 studies (9%) were published between 1998 and 2006, rises in the publication frequency can be seen in the years 2007 and again in 2015. A noticeable and steady publication frequency can be observed since 2015 where the publication frequency almost doubled compared to former years. This also indicates that the research field examining the handling of NFRs in DevOps is still in an early stage, compared with other fields in software engineering but gaining more interest in recent years. The continuous rise between 2007 and 2015 can most probably be attributed to the rising academic interest of NFRs in software engineering and specially to influencing works in this domain [41, 20, 3]. The second rise in publication frequency since 2015 may be explained with the advent of the DevOps culture that triggered respective academic research in this area [42, 43, 8].

Table 4: Main publication venues of the studies.
5 Focus areas of NFRs in DevOps (RQ2)

The 142 primary studies cover a multitude of different focus areas – software quality, operational aspects, the structuring of source code to ensure exchangeability of developers, or the mapping of software artefacts to value streams. We categorized the described NFRs in DevOps by 7 focus areas, according to the classification scheme elaborated in Table 13. This classification scheme was derived from the overall focus areas we repeatedly encountered when reviewing the primary studies during piloting the search string (cf. Section 3.3). In this section we illustrate the dominant focus areas of NFRs in DevOps and the typical research and contribution facets of each focus area. Complementary, we describe the themes and objectives of each focus area along with examples in Section 6.

5.1 Customer focus area

We selected 38 studies (27%) of the study population to be relevant for this focus area, as they elaborate on methods for increasing customer experience, sketching novel features, and monitoring customer-centered improvements throughout the DevOps cycle. In Figure 6 we show the distribution of the research and contribution facets of the studies related to this focus area, along with the 5 main themes recurrently described in the studies.

The majority of studies in this area follows validation research principles, i.e., irrespective their novelty these approaches have not been empirically validated. Only 7 studies in this area are empirically validated (evaluation research facet). However, 6 studies elaborate on concrete practical experiences in the context of customer-focused NFRs in DevOps. These are also supported by 3 theoretical proposals sketching new ideas, mainly for the prioritization and alignment of agile requirements to increase customer experience. Considering the contributions of the studies, most studies contribute theories and concepts or report on lessons learned either from a software/requirements engineering or product management perspective. Models and frameworks for customer-centricity, supported through NFRs in DevOps, are contributed by 13 of the studies.

5.2 Development focus area

In total, 26 of the 142 studies (18%) elaborate on NFRs in DevOps that focus on the efficiency of the software development process, e.g., certain restrictions that must be obeyed at an early development or requirements specification stage or particular considerations for continuous integration and delivery. We again picture the distribution of the research and contribution facets as well as the 5 main themes of the respective studies in Figure 7.

Considering the research facets, in this group most studies are empirically (8 studies, evaluation research facet) or theoretically (6 studies, validation research facet) validated. This most likely can be explained through the high availability of data accruing in the development process as well as the availability of experts that can be consulted for empirical studies in this context. Contrarily, 12 studies (46%, comprised of 2 experience reports, 5 solution proposals, and 5 opinion papers) of the 26 studies focusing on development-centered NFRs have not used any form of validation.
The majority of 15 studies (58%) in this focus area contribute practical experiences, comprised of guidelines (6 studies) and lessons learned (9 studies). Concrete frameworks, methods, and models applicable to development-focused NFRs are only contributed by 5 studies (19%).

5.3 Operation focus area

This focus area comprises studies addressing special characteristics and requirements towards the software that must be regarded primarily during its operation. The selected studies of this focus area amount to 20 studies (14%) of the overall study population and can be split up into 3 prime themes.

Again considering the research facets, only 2 of the 20 studies (10%) are empirically validated and the benefits and drawbacks clearly elaborated (evaluation research facet). Contrarily, 8 of the 20 studies (40%) use literature reviews or are based on quantitative case studies (validation research). Compared to these numbers, only 8 of the 20 studies (40%, comprised of 4 philosophical papers and 4 solution proposals) lack any validation but contribute innovative new ideas to NFRs related to software operation.

A proportionally large share of 9 of 20 studies (45%) representing this focus area contribute guidelines or report on lessons learned from practical software projects. Concrete approaches for handling software operation-focused NFRs are contributed by 6 studies (30%, comprised of models, methods, and frameworks). Finally, theoretical inputs to this focus area come from 5 studies (25%).

5.4 Governance focus area

Studies elaborating on NFRs that focus on (legal) liabilities, regulatory or technological compliances that must be obeyed and monitored during DevOps are captured by the governance focus area. We selected 41 studies (29%)
being representative for this focus area and extracted 3 main themes linked with the NFRs described in the studies, as illustrated in Figure 9. In this focus area, 19 of 36 studies (53%, comprising 11 philosophical and 8 opinion papers) can be categorized as being solely theoretical and thus dominate among the research facets. Apparent is the small number of experience reports in this focus area, only being attributed to 2 studies (6%). This is interesting insofar, as the comparatively high number of theoretical papers indicates a certain relevance of the related topics, at least from an academic perspective. Contrarily, practical approaches for handling governance-focused NFRs in DevOps are presented by 14 studies (39%), comprised of 8 studies being empirically validated (evaluation research facet) and 6 studies presenting literature reviews or quantitative, labor-driven experiments.

The dominance of theoretical works can also be observed among the contribution facets of the works, totaling to 19 studies (53%). Operational approaches for handling governance-focused NFRs in the DevOps cycle are contributed by 12 studies (33%, comprised of 1 model, 5 methods, 5 frameworks, and 1 tool described in the studies). Practical guidance for implementing governance-centered NFRs in DevOps is contributed by 10 of the 36 studies (28%, comprised of 1 guideline, 8 lessons learned, and 1 advice).

5.5 Technical quality focus area

This focus area addresses the common engineering-focused NFRs of software, ranging from static qualities such as the maintainability of the source code to dynamic qualities such as the response time or memory consumption. Due to the existing classification schemes, such as ISO/IEC 25010 [46], the themes described in the studies were categorized on a much finer level than of the other focus areas. Figure 10 illustrates the primarily engineering-oriented themes of this focus area. Also, due to the broad coverage of this type of NFRs in academic literature, the majority of studies retrieved from the databases are applicable to this focus area. Overall, we selected 59 studies (42%) for this focus area and extracted 11 representative themes. With 21 respective studies (36%), validation research takes the greatest share among the research facets, followed by 10 studies (17%) applying evaluation research methodologies. Compared with the 47% of studies attributed to other research facets (comprised of 12 philosophical, 6 solution proposals, 8 opinion papers, and 2 experience reports) the emphasis in this focus area apparently is on validated research. The majority of research in this focus area is conducted theoretically through quantitative testing methods or conducting experiments with prototypes. These studies nonetheless lack a clear elaboration on the specific benefits and limitations of their approaches in practical contexts. However, a very high number of studies applied empirical methods additionally. Specially, these studies examined the use of certain measurement or evaluation techniques of NFRs in practice or tested novel approaches in practical settings and industrial contexts followed by e.g., expert interviews from different domains. Also interesting is the comparatively high number of philosophical papers, which e.g., sketch possible ways of intertwining functional and non-functional requirements [47] or challenge the scope and notion of NFRs and their demarcation from functional requirements [16, 17].

We found 17 studies (29%) contributing concrete methods for handling quality-related NFRs in DevOps, complemented by 8 studies (14%) describing suitable models and 5 studies (8%) presenting frameworks for that purpose. Practical experiences for tackling software quality particularly in DevOps are contributed by 9 studies (15%) in the form of concrete advices and by 4 studies (7%) elaborating lessons learned in handling quality-related NFRs in DevOps. Theoretical contributions such as e.g., classification schemes come from 13 of the 59 studies (22%).
5.6 Organization focus area

Studies examining NFRs in DevOps that target the organization level within companies are summarized in this focus area. We selected 45 of the 142 studies (32%) to be applicable for this focus area and subdivided their described NFRs into 7 themes, as illustrated in Figure 11. Implicitly, the NFRs of this focus area address the organizational capabilities and properties that must be in place to effectively implement business-driven themes with software in a company. Thus, they address human factors such as motivation or the required support for skills growth as well as team/supplier communication effectiveness. In contrast to other focus areas, the respective NFRs can mainly be expressed and evaluated on a qualitative basis. We categorized 21 studies (47%, comprised of 16 opinion and 5 philosophical papers) as theoretical research works without empirical validation. On the contrary side, 16 studies (36%, comprised of 13 validation and 3 evaluation research works) presented validated research, mainly through systematic or narrative literature reviews. Due to the applied research methods, these studies do not claim for practical applicability of their findings. A small number of 3 studies applied research methods that also allow to examine specific benefits of their approaches, e.g., through conducting expert interviews or case study research. Lastly, 8 studies (18%, comprising 1 solution proposal and 7 experience reports) examine the handling of organization-focused NFRs in practice and report about possible ways for improvement and practical challenges, without sketching a generally applicable and validated methodology.

In total, 16 studies (13%) in this focus area contribute theoretical concepts such as success factors for agile transformations [48], integrations of the Scaled Agile framework (SAFe) for software development [49, 50] or differences between quality management strategies [51] on organizational level. Concrete guidance for implementing NFRs in DevOps that address organization-wide themes is contributed by 22 studies (49%, comprised of 5 guidelines, 12 studies elaborating on lessons learned, and 5 giving advices). These contributions primarily originate from multi-case studies focusing on DevOps capabilities and picture the benefits and challenges faced by the companies [52, 9]. Practically applicable artefacts, mainly complemented by empirical validations in the context of case studies, are contributed by 6 studies (13%, comprising 1 model, 2 methods, and 3 frameworks).
5.7 Business focus area

Finally, the business focus area covers all NFRs that address strategic, business, and cost/revenue considerations that manifest in software NFRs and need to be considered throughout the DevOps cycle. As illustrated in Figure 12, we selected 39 studies (27%) for this focus area and carved out 5 main themes behind the respective NFRs. The typical themes of this focus area are closely linked with elements of software business models [53, 54]. The fulfillment of these NFRs is mainly evaluated through dynamic measures. The largest portion of studies in this focus area, totaling 20 studies (51%, comprising 7 philosophical and 13 opinion papers), deal with business-focused NFRs in DevOps from a solely theoretical perspective, e.g., to outline business models specially for software [55], reflect on the suitability of ROI indicators for software [56], or sketch cost and value estimation techniques [57]. These theoretical and often biased works express personal opinions or future research directions and are complemented by 14 studies (36%) following sound validation methods. These studies have either evaluated a concrete methodology in practice (8 studies, evaluation research facet) and elaborate on their benefits and limitations, e.g., to guide value estimation in software projects [40] or conducted literature reviews in any form (6 studies, validation research facet) particularly about business models and value creation from software [39, 58]. Lastly, 5 studies (13%) elaborate on practical experiences...
(4 studies) and implementation solutions (1 study) for handling business-focused NFRs in DevOps. Particularly these studies focus on the monitoring of the respective NFRs and how to map business-level objectives to software NFRs.

Considering the contribution facets of the studies, there is an emphasis on theoretical works (13 studies, 33%) examining representative performance indicators that can be applied to software products. Research artefacts that facilitate the practical handling of business-focused NFRs in DevOps, e.g., through methods and tools for deriving quantitative software performance indicators for software products, are contributed by 8 studies (21%, comprised of 2 models, 3 methods, 1 framework and 2 tools). Best-practices from own or observed experiences of the authors and implementation guidelines are presented by 18 studies (46%, comprising 7 studies presenting guidelines, 6 studies reporting on lessons learned and 5 studies giving concrete advices).

6 Themes and objectives of NFRs in DevOps (RQ3)

In this section we describe the recurrent themes of NFRs in DevOps that we identified in the studies and the typical objectives that are linked with them. We group this description by the focus areas presented in the previous section.

6.1 Themes and objectives behind NFRs of the customer focus area

The customer-focused themes of NFRs in DevOps target on optimizing the contributed value to the customer, as illustrated in Table 5. An emphasis is on monitoring and analyzing user interaction with the software for data-driven software improvement and shortening of release cycles.

| Theme                              | Frequency | Primary studies |
|------------------------------------|-----------|-----------------|
| Feature ideation from customer feedback | 15        | [59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69] |
| Requirements validation           | 3         | [70, 71, 72]    |
| Customer value creation           | 8         | [73, 74, 75, 76, 77, 78, 79, 80, 81] |
| Release cadence                   | 4         | [82, 83, 84, 85] |
| Customer-centered epics prioritization | 8        | [86, 87, 88, 89, 90, 91, 92, 93] |

Table 5: Themes and objectives of customer-focused NFRs.

- **Feature ideation from customer feedback**: Gathering continuous feedback from the customer for software improvement as well as the ideation of new features. The focus of the improvement mainly is on the functional suitability of the software. For feature ideation, quantitative user interaction data (from user monitoring) is complemented with qualitative data from user surveys.

- **Requirements validation**: Validating the relevance of user requirements throughout the development cycle, e.g., through frequent validation cycles with customers.

- **Customer value creation**: Estimating the contributed value of software throughout the development cycle, e.g., through a "customer needs scorecard" [77] or the analysis of user queries [80].

- **Release cadence**: Shortening the time between planning and provisioning of software changes.

- **Customer-centered epics prioritization**: Prioritizing epics and user stories by contributed value of the software change for the user. Contributed user value is estimated e.g., through goal-pursuit time from monitored user interaction [85].

6.2 Themes and objectives behind NFRs of the development focus area

The themes associated with development-focused NFRs in DevOps target on reducing failure rates in the software development lifecycle, mostly through frequent feedback loops and efficient tool support. We illustrate these themes in Table 6 and the objectives sequentially.

| Theme                      | Frequency | Primary studies |
|----------------------------|-----------|-----------------|
| Delivery pipeline maturity  | 8         | [38, 39, 40, 41, 42, 43, 44, 45, 46] |
| Continuous integration     | 4         | [47, 48, 49, 50] |
| Continuous delivery        | 4         | [51, 52, 53, 54] |
| Development tool versatility | 4        | [55, 56, 57, 58] |

Table 6: Themes and objectives of development-focused NFRs.
Development task complexity | 6 |
|-----------------------------|---|
Table 6: Themes and objectives of development-focused NFRs.

- **Delivery pipeline maturity**: Closing feedback loops to facilitate actionable analytics of the data accruing on the different systems in DevOps. The degree of actionability is assessed through concrete metrics and reflects the maturity of the delivery pipeline.
- **Continuous integration**: Assuring correct system, software, and service behavior through continuous integration of smaller code changes into the codebase of the whole product.
- **Continuous delivery**: Reducing the failure rate after software changes through deploying the software in short cycles. Also, the aim is on gaining understanding of the impacts of the software change on operational characteristics and improve architectural decisions thereof [38].
- **Development tool versatility**: Assuring the suitability and flexibility of the development environments (e.g., IDEs, source code repositories, issue trackers) to support engineers in their development activities and the tracking between source code and compiled software on different systems.
- **Development task complexity**: Reducing complexity of development tasks, e.g., through architectural and code blueprints, best practices, and guidelines for development tasks.

6.3 Themes and objectives behind NFRs of the operation focus area

The main objective of the themes linked with operation-focused NFRs in DevOps address the monitoring, debugging, and tracing of runtime artefacts, as illustrated in Table 7.

| Theme                                      | Frequency | Primary studies               |
|--------------------------------------------|-----------|-------------------------------|
| Artefact runtime traceability              | 6         | [73, 94, 87, 95, 96, 35]      |
| Monitoring process maturity                | 6         | [38, 48, 87, 24, 9, 45]        |
| Post-deployment debugging                  | 8         | [59, 62, 97, 58, 84, 96, 71]   |

Table 7: Themes and objectives of operation-focused NFRs.

- **Artefact runtime traceability**: Establishing links between source code artefacts and runtime entities [94]. Specially, this needs to regard different versions of the software deployed on different systems and allow to relate monitored operational data back to the originating source code version.
- **Monitoring process maturity**: Effectively and efficiently monitor the software in operation and automatize the integration of the monitoring data for software analytics [24].
- **Post-deployment debugging**: Facilitating debugging of the operational software, e.g., upon deviations between expected and actual software behavior. Particularly in system-of-system architectures and transactional systems this may lead to specific challenges arising from different network protocols/architectures, and firewalls [62].

6.4 Themes and objectives behind NFRs of the governance focus area

In this focus area, the objectives of the themes behind the NFRs are on assuring data privacy, enterprise architecture, and regulatory compliance. We picture the themes and their frequency in the studies in Table 8 and the respective objectives afterwards.

| Theme                                | Frequency | Primary studies               |
|--------------------------------------|-----------|-------------------------------|
| Data privacy                         | 10        | [99, 38, 100, 91, 101, 57, 102, 69, 103, 104] |
| Liabilities and regulatory compliance | 19        | [105, 59, 106, 48, 89, 109, 55, 20, 57, 78, 108] |
| Enterprise architecture alignment     | 7         | [118, 113, 19, 44, 109, 114, 115] |

Table 8: Themes and objectives of governance-focused NFRs.
• **Data privacy:** Assuring privacy of the data accruing on the different systems, comprised of e.g., interaction traces and processed sensitive data from the user [100].

• **Liabilities and regulatory compliance:** Addressing how legal obligations and duties can be implemented by the software, such as the processing of licensing data [55], the recording of presented information to customers in financial advisory processes [35], the calculation scheme for financial ratings of customers, or the processing of data for identifying customers in accounting applications [109].

• **Enterprise architecture alignment:** Aligning and integrating the software into the enterprise application landscape through architectural guidelines and frameworks, e.g., TOGAF [116] or ATAM [117].

### 6.5 Themes and objectives behind NFRs of the technical quality focus area

The themes in the quality focus area mainly reflect common static and dynamic software quality factors, as also defined in e.g., the ISO/IEC 25010 standard [46]. However, as shown in Table 9, the frequency of studies examining certain themes varies among the studies which indicates that they are differently important in DevOps. Due to the apparent similarities of the themes to the ISO 25010 standard, we primarily outline important differences or additions of the respective NFRs in DevOps.

| Theme                  | Frequency | Primary studies |
|------------------------|-----------|-----------------|
| Usability              | 4         | [118, 119, 120, 81] |
| Resilience             | 3         | [121, 122, 84]  |
| Scalability            | 5         | [18, 82, 65, 50, 37] |
| Performance            | 10        | [123, 12, 24, 125, 126, 15, 127, 128, 109] |
| Framework compliance   | 3         | [129, 130, 131]  |
| Security               | 4         | [75, 132, 64, 133] |
| Extensibility          | 2         | [73, 137]        |
| Test quality           | 2         | [134, 135]       |
| Maintainability        | 4         | [136, 137, 138, 139] |
| Data-driven deployment | 3         | [74, 68, 70]     |
| Safety                 | 19        | [140, 141, 142, 143, 16, 144, 17, 66, 145, 146, 147, 148, 149, 150, 151, 104, 152, 153, 112] |

Table 9: Themes and objectives of technical quality-focused NFRs.

• **Usability:** Reducing the time and cognitive load to accomplish goals with software. Task-based methods allow concrete quantification and automatized evaluation of usability [120, 81].

• **Resilience:** Supporting flexible adaptations of software to ensure product robustness and particularly to diminish remediation costs in DevOps [121].

• **Scalability:** Facilitating automated deployments to dynamically react on usage peaks. In the DevOps context this involves inserting probes into the source code prior to deployment that can trigger automatic deployments thus ensuring elasticity of the system [18].

• **Performance:** Providing results to the user of the software in a responsive fashion independently on whether the provided software is a graphical user interface (GUI) or a service endpoint (API). In addition, performance requirements shall be explicated and evaluated on the level of individual features, balanced with their strategic and economic value [142, 123].

• **Framework compliance:** Reducing complexity, training efforts, and maintenance costs by adhering to predetermined and evaluated frameworks. For this purpose, most companies use library blueprints or ready-to-use build profiles, which can be integrated with little effort in the DevOps toolchain.

• **Security:** Specially with the proliferation of software ecosystems shared between multiple companies, end-to-end encryption of entered user data and cascaded cryptographic blocks of the user journey are gaining more attention. Most of these security requirements need to be fulfilled on feature-level and require operational support for acquiring the measures in a DevOps context.

• **Extensibility:** Facilitating modification of the software, e.g., through separation and decomposition of functional blocks into self-contained units of work. In DevOps, apart from static code metrics, also functional
and latent dependencies between software components can be traced. This can for instance be achieved through
labeling software components and extracting cause-effect-relationships from operational data.

- **Test quality:** Assessing test processes, methods, sources, and tools used for testing in DevOps, i.e., test
strategies, the degree of automation, test coverage, test report dissemination and handling of failed test cases.
- **Maintainability:** Lowering maintenance costs through adhering e.g., to design best practices, coding styles and
the early elimination of code bad smells. Due to the availability of operational data in DevOps, maintainability
requirements shall be balanced with actual feature usage [137].
- **Data-driven deployment:** Evolving development practices to the point where they could continuously deploy
and validate individual features, rather than preparing larger product releases. Apparently, this requires
continuous collection of post-deployment data for quantitative analysis of this data. These data allow to derive
development activities and suitable indicators of deployment efficiency [68].
- **Safety:** Giving guarantees for certain quality attributes under predefined conditions. Specially with the
proliferation of software-centric devices in new areas such as autonomous driving or drones, the monitoring of
safety quality attributes in a DevOps context gains increasing industry relevance [144].

### 6.6 Themes and objectives behind NFRs of the organization focus area

The organization-focused themes of NFRs in DevOps target on ensuring organizational agility through harmonizing
team, supplier, and market requirements. An important and recurrent center point among the themes is the human factor
and its influence on software development and operation, as illustrated in Table 10.

| Theme                           | Frequency | Primary studies          |
|---------------------------------|-----------|--------------------------|
| Market responsiveness           | 8         | [154, 155, 123, 148, 156, 49, 50, 157, 12] |
| Resource fluidity               | 3         | [158, 49, 50]            |
| Motivation                      | 3         | [99, 106, 159]           |
| Team-supplier communication     | 5         | [89, 155, 108, 160, 59]  |
| Cross-team integration          | 10        | [56, 156, 123, 146, 89, 62, 156, 90, 50, 161] |
| Skills growth                   | 7         | [142, 148, 102, 146, 24, 9] |
| Cross-domain convergence        | 7         | [89, 154, 138, 163, 102, 51] |

Table 10: Themes and objectives of technical organization-focused NFRs.

- **Market responsiveness:** Decreasing the time to respond to customer requests by concretizing them on
  the level of software functionality. This can be achieved in DevOps e.g., through extracting and mapping
  operational software characteristics to metrics for Quality Function Deployment (QFD) [157].
- **Resource fluidity:** Applying software engineering methods, best practices, and standardized tools that allow
  to shuffle work between the organization when priorities change.
- **Motivation:** Leveraging internal sources for software improvement through providing feedback directly and frequently to a certain engineer. In DevOps this can be accomplished for instance through labelling software artefacts and analyzing the commit history automatically.
- **Team-supplier communication:** Empowering teams to drive decisions regarding development and operation
  of the software concertedly with outside stakeholders, such as e.g., suppliers. Apart from consistent communication channels, in DevOps this requires thorough documentation of the software artefact, specially of operational characteristics and all runtime metadata [89].
- **Cross-team integration:** Establishing inter-company collaboration among teams of different domains to improve the software value stream [86] for the company. Apart from cross-discipline training of the software engineers, an unambiguous labeling of the software artefacts, a RACI (responsibility-assignment) matrix, and standardized documentation guidelines facilitate collaboration among teams [62]. Cross-functional teams shall not exceed the size of 8-12 so that they can maintain a focus on a specific aspect of the software [36].
- **Skills growth:** Providing training materials and mentoring to acquire skills required for accomplishing the
  DevOps-related tasks. Having a supportive and visible support infrastructure on the level of concrete features
  and recurrent tools is critical for the wholesale success of software product [48]. Particularly for DevOps this
  requires establishing links between software artefacts, issue trackers, and deployment tools for capturing and
documenting all relevant data throughout the lifecycle.
Cross-domain convergence: Designing, developing, operating, and continuously improving software, so that it can be reused across application domains, e.g., mobile and pervasive sensing systems that share and process data among autonomous systems [144]. Primarily this affects the selection of suitable network protocols for integrating the applications in the DevOps environment. Respective environments for this purpose must be able to deal with unreliable data connections and time-delayed delivery of operational data of the developed applications [89].

6.7 Themes and objectives behind NFRs of the business focus area

Value capture, creation, and optimization throughout the software lifecycle is the prime objective behind business-focused NFRs in DevOps.

| Theme                        | Frequency | Primary studies |
|------------------------------|-----------|-----------------|
| Mean time to value           | 3         | [36, 9, 164]    |
| Transaction costs            | 9         | [105, 141, 39, 62, 49, 58, 80, 165, 35] |
| Ecosystem valuation          | 9         | [40, 155, 166, 89, 66, 55, 167, 138, 69] |
| Product market share         | 10        | [168, 136, 86, 55, 77, 146, 169, 170, 157, 35] |
| Value stream mapping         | 8         | [171, 172, 144, 86, 57, 87, 173, 157] |

Table 11: Themes and objectives of business-focused NFRs.

- **Mean time to value**: Reducing the cycle time, i.e., the time between an idea and its realization as software in production. Operationally, the respective measures can be acquired from issue trackers and deployment systems [36].

- **Transaction costs**: Balancing the software development and operation costs for the manufacturer with the perceived value of using the software for the customer. Also, customers conceive of costs in terms of the offer price plus all additional changes they need to undertake in order to use software [105]. The cost for the manufacturer accruing in the DevOps cycle can be calculated indirectly, e.g., through monitoring the frequency of bugs and code changes of particular features. Contrarily, the value of the software for the user can be evaluated using qualitative feedback methods (e.g., in-app surveys, ratings) that complement quantitative measures such as e.g., the invocation frequency or cause-effect analysis of customer behavior and offer price [66].

- **Ecosystem valuation**: Assigning quantitative measures (either monetary or in form of a company balanced scorecard) to an ecosystem and its services [40]. A software ecosystem consists of a software platform, internal/external developers and a community of domain experts. These domain experts help adapt or modify the software to satisfy the users’ needs [155]. In DevOps, these quantitative measures needed for thorough ecosystem valuation can be acquired e.g., from ERP- and billing systems, bug trackers, development and operational systems. Overall, this allows to dynamically balance the company’s efforts for participation in the software ecosystem based on actual user behavior and thus optimize the business value of the software for the company.

- **Product market share**: Assessing and evaluating the impact of changes of the provisioned software on its market share, particularly through gap analysis between potential and actual market share, competitor analysis and value-estimation of new features [67, 170]. Similar to ecosystem valuation, this theme requires quantification of external factors e.g., through mining textual product reviews, designing novel features, and weighting them according to estimated economic value added (EVA) and return on invest (ROI) [168, 169]. In DevOps, external factors such as e.g., the results from A/B testing, must then be considered in conjunction with internal factors such as e.g., business performance indicators, to decide upon concrete software engineering activities [136].

- **Value stream mapping**: Identifying and addressing delays and non-value-added activities in DevOps to accomplish the shortest sustainable lead time. The mapping between software artefacts and the business model’s value streams is the prerequisite for assessing the business value of software features, as also advocated in the Scaled Agile Framework (SAFe) [173]. For implementing this theme in DevOps, application lifecycle management (ALM) tools can be used to acquire the measures of the operational value stream, i.e., the steps used to provide goods or services to the customers. As an example, the invocation frequency of a feature in relation to the update cadence and its offer price can serve as an indicator for its value for the customer. These indicators can then be analyzed based on the cost and revenue model [174] to derive concrete activities for the development value stream, i.e., the steps used to create products, systems, or feature capabilities [86].
7 Discussion

In this section we summarize the principle findings from this systematic mapping study and sketch their implications for researchers and practitioners.

7.1 Principle findings

Our work outlines the broad scope and focus areas of NFRs, becoming apparent through the pursued objectives originating from different domains. Particularly, our study shows that NFRs to a large extent address non-engineering qualities of software which are not covered e.g., through the ISO/IEC [46] which subsequently result in little if any practical support for them in DevOps. This is problematic insofar, as operational data accruing in the DevOps context, and generally in the software development lifecycle, that are possibly suitable for guiding software development is not utilized. Compared with the other focus areas of NFRs, the majority of analyzed studies focus on technical qualities, such as e.g., maintainability of the source code, safety, and deployability. This may be due to the concrete definition of technically-oriented NFRs in common literature and specifically in the ISO/IEC specification [46]. However, the importance of aligning software engineering, organizational, and governance related objectives can also be inferred from the number of studies elaborating on challenges arising from this misbalance. As an example, the requirement for collecting operational feature usage data is a prerequisite for A/B and feature testing [74, 78] which must be implemented during software development. However, the customer-focused NFR aiming on feature-ideation from user interaction (cf. Section 6.1) itself requires an overall product strategy and ecosystem valuation, so that the acquired measures can be suitably evaluated. In addition, the maintainability requirements for new software features derived from actual user interaction might probably be higher than of features having less strategic importance for a company. This example shows the required indentation of different NFR focus areas, i.e., business, customer, and development, to effectively build software in DevOps following the idea of value-based software engineering [56]. In addition, our study confirms the vagueness of the scope of "non-functional requirements" itself, which has already been stressed by several authors [175, 16, 93]. Also, the alignment between governance, regulatory compliance, and software development is explicated as being crucial in many studies [55, 105, 48, 135] and the lack of methods, to address these objectives in a balanced manner, underlined. Surprisingly many studies elaborate on the human factor in software engineering and its impact on the final quality of the software product, but neither present applicable means to express, nor methods to measure and evaluate the respective NFRs in DevOps.

7.2 Implications for researchers and practitioners

This study seeks to give an overview about typical focus areas, themes, and objectives of NFRs in DevOps, to identify existing research gaps and to sketch possible future research directions. Though NFRs being an established concept in software engineering, there is a continuous and rising interesting in this topic when it comes to the handling of NFRs in DevOps, which also became apparent in the analysis of the publication frequency (cf. Figure 5). While multiple studies describe (theoretical) methods, models, and frameworks for handling NFRs in DevOps, few of them are validated empirically. Also, besides classical engineering-oriented NFRs, the automatic evaluation of NFRs arising from non-technical focus areas in DevOps, e.g., focusing on business aspects, customers, and governance requirements, is still hindered by the absence of a common collection of metrics for these focus areas. These metrics also are the prerequisite for balancing the objectives of the different NFRs focus areas, e.g., to quantitatively express the allowed maintenance effort for a software feature based on its usage. The operationalization of non-engineering-focused NFRs and their evaluation, e.g., in relation to a company’s business model, plays a key role when it comes to software-based digitalization in companies [6, 7, 176]. As this study is based on a literature analysis, the overall question remains which objectives are actually important from a practical perspective and also how the results from evaluating the NFRs of the diverse focus areas can be most effectually utilized in DevOps.

In this frame, we are working on an approach for operationalizing and evaluating NFRs in DevOps. Our approach is based on an operational software quality model [177] to specify feature-dependent NFRs, respective measures, and suitable instruments for their acquisition in an automatable manner. The quality model is complemented by a constraint definition language that utilizes these measures to express complex NFRs and evaluate their fulfillment in DevOps. Accordingly, the classification of focus areas, themes, and objectives of NFRs presented in this study are the foundation for specifying NFRs in DevOps through constraints and measures using this operational quality model.

8 Threats

Though we conducted this systematic mapping study and the snowballing procedure according to the respective guidelines [27, 28], we recognize the following threats to the validity of the study:
This paper presents the results from a systematic mapping study examining the focus areas, themes, and objectives of NFRs in the DevOps context. We retrieved 229 candidate studies from 5 academic databases, of which 114 were selected as primary studies. Also, we included a snowballing step to capture studies that elaborate on NFRs which not adhere to the strict technically-oriented notion of this term but nonetheless have an impact on the design, development, and operation of a software system. This step again resulted in 27 primary studies being selected for inclusion, with the result set totaling to 142 primary studies for this mapping study. Data were extracted from these studies and then categorized by a defined classification schema. Themes and objectives of NFRs in DevOps described in the studies were iteratively synthesized from labeled text fragments and then summarized per focus area. The publication frequency over the years shows a continuous interest in this field with higher increases since 2015, with the studies cited in the initially retrieved papers were relevant for answering the research questions and adhered to the inclusion/exclusion criteria we included these studies in the subsequent analysis. Thus, we are confident that we captured the majority of the relevant studies and missed only little, if any, significant studies not matched by the search strings.

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9 Conclusion

This paper presents the results from a systematic mapping study examining the focus areas, themes, and objectives of NFRs in the DevOps context. We retrieved 229 candidate studies from 5 academic databases, of which 114 were selected as primary studies. Also, we included a snowballing step to capture studies that elaborate on NFRs which not adhere to the strict technically-oriented notion of this term but nonetheless have an impact on the design, development, and operation of a software system. This step again resulted in 27 primary studies being selected for inclusion, with the result set totaling to 142 primary studies for this mapping study. Data were extracted from these studies and then categorized by a defined classification schema. Themes and objectives of NFRs in DevOps described in the studies were iteratively synthesized from labeled text fragments and then summarized per focus area. The publication frequency over the years shows a continuous interest in this field with higher increases since 2015, with the studies cited in the initially retrieved papers were relevant for answering the research questions and adhered to the inclusion/exclusion criteria we included these studies in the subsequent analysis. Thus, we are confident that we captured the majority of the relevant studies and missed only little, if any, significant studies not matched by the search strings.

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While the term "non-functional requirement" is widely used in academic literature as well as in practice, in many cases a clear distinction between non-functional and functional requirements is difficult [175][16]. Also, many studies actually describe non-functional software requirements implicitly, particularly if these studies do not originate from the software engineering domain. To mitigate this threat, we conducted a snowballing procedure prior to the data analysis. Only if the primary studies cited in the initially retrieved papers were relevant for answering the research questions and adhered to the inclusion/exclusion criteria we included these studies in the subsequent analysis. Thus, we are confident that we captured the most relevant studies contributing to a broader understanding also of non-engineering focused NFRs in software projects.

We addressed this threat twofold: first, by composing the search string of multiple keywords each individually expressing a relevant aspect of NFRs in DevOps [30] and second, by piloting this search string with different databases multiple times to evaluate the effect of the keywords onto the result set. However, the precision of the retrieved result set also depends on the quality of the keywords used in the searched studies. Also, we only used databases that cover the software engineering research very well and also read the titles, abstract, and conclusion (if needed) to decide upon the selection of a study. Thus, we are convinced to have captured the majority of the relevant studies and missed only little, if any, significant studies not matched by the search strings.

Though we are not aware of any biases regarding the selection of the studies, we recognize that unsuitable definition of the inclusion and exclusion criteria may lead to attrition bias. To mitigate this threat, both researchers defined these criteria upfront in an unambiguous manner. Also, we revised these criteria during multiple when piloting the search string to assure to not exclude relevant studies. When deciding upon the selection of studies, we discussed any disagreements regarding the inclusion and exclusion of studies until both researchers agreed on a common decision.

Biased judgments are also possible during data extraction and analysis, i.e., which text passages in the studies are labeled and which codes are derived and refined thereof. We mitigated this threat by defining the concrete properties to extract from the studies and the way to document this data upfront. Also, the thematic refinement of the codes and the encoded text fragments were discussed between both researchers until we agreed on a solid set of codes.

9 Conclusion

This paper presents the results from a systematic mapping study examining the focus areas, themes, and objectives of NFRs in the DevOps context. We retrieved 229 candidate studies from 5 academic databases, of which 114 were selected as primary studies. Also, we included a snowballing step to capture studies that elaborate on NFRs which not adhere to the strict technically-oriented notion of this term but nonetheless have an impact on the design, development, and operation of a software system. This step again resulted in 27 primary studies being selected for inclusion, with the result set totaling to 142 primary studies for this mapping study. Data were extracted from these studies and then categorized by a defined classification schema. Themes and objectives of NFRs in DevOps described in the studies were iteratively synthesized from labeled text fragments and then summarized per focus area. The publication frequency over the years shows a continuous interest in this field with higher increases since 2015, with the studies being predominantly published in journals and on conferences. Most studies in this field contribute theories, methods, models, or present lessons learned from handling NFRs in DevOps in practical settings. However, the majority of these studies describe artefacts which are not yet practically implemented and thus lack an empirical validation. From the studies, we condensed 7 recurrent focus areas of NFRs in DevOps, ranging from development and operation to governance- and business-oriented areas. The most pressing objectives pursued with NFRs in DevOps are to assure safe and responsive operation of the software (technical quality focus), facilitate cross-team integration of experts from different domains (organization focus), ascertain regulatory compliance of the software (governance focus), utilize customer interaction with the software for prospective feature ideation (customer focus), create and safeguard product market share (business focus), optimize the delivery pipeline (development focus), and to facilitate post-deployment debugging (operation focus).
For future work, typical metrics for the NFRs of the different focus areas and usage scenarios in practice, as well as methods for their operationalization shall be explored by researchers, at best complemented with an empirical validation. Furthermore, methodological and tool support is needed to aid practitioners specifying these NFRs in a way that can be utilized in a DevOps context.
Appendices

A

| Category | Description |
|----------|-------------|
| **P1: Research facet, adapted from Petersen [27] and Wieringa [31]** | |
| Experience report | Similar to opinion paper, these works express practical experiences of the author with a method or technique. Often these reports come from practitioners who have used a specific method in practice and can thus provide valuable insights into possible ways for improvements. |
| Evaluation research | Describes the investigation of a problem or an implementation of a solution for it in practice, along with an evaluation for the solution. It also shows the benefits and drawbacks of the technique. |
| Validation research | The presented techniques are novel and have not yet been practically implemented, e.g., work done in laboratory. |
| Philosophical paper | The work sketches a new way on looking on things, such as taxonomies or concepts. Evaluation criteria are the originality, soundness, and transparency of the work. |
| Solution proposal | A solution technique for a problem is presented along with an argumentation for its relevance, but an evaluation of the solution is missing. The solution must be novel or demonstrate a significant enhancement of a previous approach. |
| Opinion paper | The work presents the personal opinion of the author about what is good or bad about a technique and how it can be improved. Such works do not rely on related works or sound research methodologies, but can possibly sketch new ways to address known problems. |

| **P2: Contribution facet, adapted from Shaw [32] and Paternoster [33]** | |
| Model | An abstraction of an observed reality by concepts or related concepts after a conceptualization process. |
| Method | Method or technique for handling non-functional requirements in the planning, management, development, or operation of software. |
| Theory | Construct of cause-effect relationships of determined results. |
| Framework | Combination of methods with distinct conditions which method shall be applied under which circumstances and with defined input and output parameters. |
| Guideline | List of advises, compilation, or interpretation of obtained research results. |
| Lessons Learned | Commented set of outcomes with fact-based recommendations, directly concluded from the obtained research results. |
| Advice | Generic recommendation, influenced by personal opinions from the author. |
| Tool | Technology or software application used for handling non-functional requirements in the planning, management, development, or operation of software. |

Table 12: Classification scheme for research and contribution facets.

| Category | Description |
|----------|-------------|
| **P5: Focus area of NFRs described in study** | |
| Customer | Studies describing NFRs related to increasing customer experience or value, e.g., through user-centered value estimation techniques or passive user involvement, e.g., through user monitoring. |
| Development | Approaches capturing NFRs related to the software development, integration and delivery process and its tools, artefacts, methods, systems, and stakeholders. |
| Operation | Works that address NFRs affecting software operation and specifically includes the tools, artefacts, methods, systems, and involved stakeholders. |
| Governance | Presents liabilities, regulatory or technological compliances and requirement alignments that need to be taken account in DevOps and affect the NFRs of the respective software. |

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Quality Works elaborating on or referring to static and dynamic quality factors of software that are linked with NFRs, e.g., the code or design quality, performance behavior or reliability.

Organization Tackles NFRs attributed to the needed agility of the organization in the DevOps context to cope with internal or external changes. Particularly this comprises staff fluctuation, training, and (third party) supplier integration.

Business Works regarding business-related NFRs that need to be taken into account in the DevOps context, e.g., to measure cost and revenue per user transaction or to evaluate fulfillment of business-driven goals with software.

Table 13: Classification schema for NFR focus areas.

| Primary Study | Research facet       | Contribution facet | Focus area   | Theme                        |
|---------------|----------------------|--------------------|--------------|------------------------------|
| 67            | Experience Report    | Lessons Learned    | Customer     | Feature Ideation             |
| 68            | Solution Proposal    | Framework          | Customer     | Feature Ideation             |
| 61            | Validation Research  | Model              | Customer     | Feature Ideation             |
| 64            | Validation Research  | Model              | Customer     | Feature Ideation             |
| 71            | Validation Research  | Method             | Customer     | Feature Ideation             |
| 65            | Evaluation Research  | Model              | Customer     | Feature Ideation             |
| 66            | Validation Research  | Lessons Learned    | Customer     | Feature Ideation             |
| 62            | Experience Report    | Lessons Learned    | Customer     | Feature Ideation             |
| 59            | Validation Research  | Lessons Learned    | Customer     | Feature Ideation             |
| 122           | Validation Research  | Guideline          | Customer     | Feature Ideation             |
| 44            | Solution Proposal    | Framework          | Customer     | Feature Ideation             |
| 69            | Evaluation Research  | Theory             | Customer     | Feature Ideation             |
| 70            | Validation Research  | Lessons Learned    | Customer     | Feature Ideation             |
| 72            | Validation Research  | Theory             | Customer     | Feature Ideation             |
| 63            | Evaluation Research  | Framework          | Customer     | Feature Ideation             |
| 73            | Validation Research  | Lessons Learned    | Customer     | Requirements Validation     |
| 61            | Validation Research  | Model              | Customer     | Requirements Validation     |
| 74            | Solution Proposal    | Model              | Customer     | Requirements Validation     |
| 75            | Validation Research  | Theory             | Customer     | Value Creation               |
| 77            | Evaluation Research  | Guideline          | Customer     | Value Creation               |
| 78            | Evaluation Research  | Lessons Learned    | Customer     | Value Creation               |
| 79            | Validation Research  | Model              | Customer     | Value Creation               |
| 80            | Philosophical Paper  | Theory             | Customer     | Value Creation               |
| 76            | Validation Research  | Theory             | Customer     | Value Creation               |
| 35            | Validation Research  | Theory             | Customer     | Value Creation               |
| 81            | Validation Research  | Model              | Customer     | Value Creation               |
| 80            | Validation Research  | Theory             | Customer     | Value Creation               |
| 84            | Evaluation Research  | Model              | Customer     | Customer-Centered Epics Prioritization |
| 82            | Validation Research  | Advice              | Customer     | Customer-Centered Epics Prioritization |
| 62            | Experience Report    | Lessons Learned    | Customer     | Customer-Centered Epics Prioritization |
| 83            | Philosophical Paper  | Theory             | Customer     | Customer-Centered Epics Prioritization |

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| Type                          | Analysis | Type          | Organization                          | Cross-Domain Convergence |
|-------------------------------|----------|---------------|---------------------------------------|--------------------------|
| Validation Research          | Theory   | Customer      | Customer-Centered                     |                          |
| Experience Report            | Lessons Learned | Customer      | Customer-Centered                     |                          |
| Philosophical Paper          | Framework | Customer      | Customer-Centered                     |                          |
| Validation Research          | Theory   | Governance    | Enterprise Architecture Alignment     |                          |
| Philosophical Paper          | Tool     | Governance    | Enterprise Architecture Alignment     |                          |
| Solution Proposal            | Framework | Governance    | Enterprise Architecture Alignment     |                          |
| Solution Proposal            | Method   | Governance    | Enterprise Architecture Alignment     |                          |
| Validation Research          | Advice   | Governance    | Enterprise Architecture Alignment     |                          |
| Experience Report            | Lessons Learned | Organization | Market Responsiveness                 |                          |
| Opinion Paper                | Advice   | Organization  | Cross-Domain Convergence              |                          |
| Opinion Paper                | Lessons Learned | Organization | Cross-Domain Convergence              |                          |
| Validation Research          | Model    | Organization  | Cross-Domain Convergence              |                          |
| Evaluation Research          | Method   | Organization  | Cross-Domain Convergence              |                          |
| Solution Proposal            | Framework | Organization | Cross-Domain Convergence              |                          |
| Opinion Paper                | Framework | Organization | Cross-Domain Convergence              |                          |
| Evaluation Research          | Theory   | Organization  | Cross-Domain Convergence              |                          |
| Evaluation Research          | Method   | Organization  | Cross-Domain Convergence              |                          |
| Opinion Paper                | Theory   | Quality       | Usability                              |                          |
| Solution Proposal            | Method   | Quality       | Usability                              |                          |
| Opinion Paper                | Theory   | Quality       | Usability                              |                          |
| Validation Research          | Lessons Learned | Operation    | Artefact Runtime Traceability         |                          |
| Validation Research          | Method   | Operation     | Artefact Runtime Traceability         |                          |
| Evaluation Proposal          | Guideline | Operation     | Artefact Runtime Traceability         |                          |
| Evaluation Research          | Method   | Operation     | Artefact Runtime Traceability         |                          |
| Philosophical Paper          | Theory   | Operation     | Artefact Runtime Traceability         |                          |
| Validation Research          | Theory   | Operation     | Artefact Runtime Traceability         |                          |
| Validation Research          | Lessons Learned | Operation    | Post-Deployment Debugging             |                          |
| Experience Report            | Lessons Learned | Operation    | Post-Deployment Debugging             |                          |
| Philosophical Paper          | Model    | Operation     | Post-Deployment Debugging             |                          |
| Philosophical Paper          | Theory   | Operation     | Post-Deployment Debugging             |                          |
| [58] | Validation Research | Guideline | Operation | Post-Deployment Debugging |
|---|---|---|---|---|
| [44] | Solution Proposal | Framework | Operation | Post-Deployment Debugging |
| [96] | Philosophical Paper | Theory | Operation | Post-Deployment Debugging |
| [71] | Validation Research | Method | Operation | Post-Deployment Debugging |
| [38] | Solution Proposal | Framework | Operation | Monitoring Process Maturity |
| [48] | Validation Research | Theory | Operation | Monitoring Process Maturity |
| [87] | Solution Proposal | Guideline | Operation | Monitoring Process Maturity |
| [69] | Validation Research | Lessons Learned | Operation | Monitoring Process Maturity |
| [9] | Experience Report | Lessons Learned | Operation | Monitoring Process Maturity |
| [45] | Evaluation Research | Guideline | Operation | Monitoring Process Maturity |
| [38] | Solution Proposal | Framework | Development | Development Pipeline Maturity |
| [86] | Opinion Paper | Guideline | Development | Development Pipeline Maturity |
| [8] | Evaluation Research | Theory | Development | Development Pipeline Maturity |
| [87] | Solution Proposal | Guideline | Development | Development Pipeline Maturity |
| [69] | Validation Research | Lessons Learned | Development | Development Pipeline Maturity |
| [69] | Evaluation Research | Theory | Development | Development Pipeline Maturity |
| [45] | Evaluation Research | Guideline | Development | Development Pipeline Maturity |
| [88] | Solution Proposal | Framework | Development | Development Pipeline Maturity |
| [73] | Validation Research | Lessons Learned | Development | Continuous Integration |
| [89] | Opinion Paper | Lessons Learned | Development | Continuous Integration |
| [78] | Evaluation Research | Lessons Learned | Development | Continuous Integration |
| [45] | Evaluation Research | Guideline | Development | Continuous Integration |
| [90] | Experience Report | Process | Development | Continuous Integration |
| [38] | Solution Proposal | Framework | Development | Continuous Integration |
| [89] | Opinion Paper | Lessons Learned | Development | Continuous Integration |
| [45] | Evaluation Research | Guideline | Development | Continuous Integration |
| [89] | Opinion Paper | Lessons Learned | Development | Development Tool Versatility |
| [91] | Experience Report | Lessons Learned | Development | Development Tool Versatility |
| [8] | Evaluation Research | Theory | Development | Development Tool Versatility |
| [49] | Opinion Paper | Theory | Development | Development Tool Versatility |
| [73] | Validation Research | Lessons Learned | Development | Development Task Complexity |
| [61] | Validation Research | Model | Development | Development Task Complexity |
| ID  | Type                  | Source                  | Field                     | Key Area                      |
|-----|-----------------------|-------------------------|---------------------------|-------------------------------|
| 92  | Validation Research   | Lessons Learned         | Development               | Development Task Complexity   |
| 87  | Solution Proposal     | Guideline               | Development               | Development Task Complexity   |
| 93  | Validation Research   | Theory                  | Development               | Development Task Complexity   |
| 44  | Evaluation Research   | Model                   | Development               | Development Task Complexity   |
| 140 | Validation Research   | Method                  | Technical Quality         | Safety                        |
| 141 | Validation Research   | Theory                  | Technical Quality         | Safety                        |
| 142 | Philosophical Paper   | Theory                  | Technical Quality         | Safety                        |
| 143 | Opinion Paper         | Advice                  | Technical Quality         | Safety                        |
| 145 | Philosophical Paper   | Advice                  | Technical Quality         | Safety                        |
| 146 | Evaluation Research   | Method                  | Technical Quality         | Safety                        |
| 147 | Philosophical Paper   | Method                  | Technical Quality         | Safety                        |
| 148 | Opinion Paper         | Advice                  | Technical Quality         | Safety                        |
| 149 | Validation Research   | Framework               | Technical Quality         | Safety                        |
| 150 | Philosophical Paper   | Theory                  | Technical Quality         | Safety                        |
| 151 | Validation Research   | Model                   | Technical Quality         | Safety                        |
| 152 | Evaluation Research   | Framework               | Technical Quality         | Safety                        |
| 153 | Evaluation Research   | Model                   | Technical Quality         | Safety                        |
| 154 | Validation Research   | Method                  | Governance                | Regulatory Compliance         |
| 155 | Validation Research   | Lessons Learned         | Governance                | Regulatory Compliance         |
| 156 | Opinion Paper         | Guideline               | Governance                | Regulatory Compliance         |
| 157 | Opinion Paper         | Theory                  | Governance                | Regulatory Compliance         |
| 158 | Solution Proposal     | Method                  | Governance                | Regulatory Compliance         |
| 159 | Philosophical Paper   | Theory                  | Governance                | Regulatory Compliance         |
| 160 | Philosophical Paper   | Theory                  | Governance                | Regulatory Compliance         |
| 161 | Evaluation Research   | Method                  | Governance                | Regulatory Compliance         |
| 162 | Philosophical Paper   | Theory                  | Governance                | Regulatory Compliance         |
| 163 | Evaluation Research   | Model                   | Governance                | Regulatory Compliance         |
| 164 | Evaluation Research   | Lessons Learned         | Governance                | Enterprise Architecture Alignment |
| 165 | Evaluation Research   | Theory                  | Governance                | Enterprise Architecture Alignment |
| 166 | Philosophical Paper   | Framework               | Governance                | Data Privacy                  |
| 167 | Solution Proposal     | Framework               | Governance                | Data Privacy                  |
| 168 | Evaluation Research   | Lessons Learned         | Governance                | Data Privacy                  |
| 169 | Experience Report     | Lessons Learned         | Governance                | Data Privacy                  |
| 170 | Evaluation Research   | Theory                  | Governance                | Data Privacy                  |
| 171 | Validation Research   | Model                   | Governance                | Data Privacy                  |
| 172 | Validation Research   | Theory                  | Technical Quality         | Usability                     |
| 173 | Validation Research   | Theory                  | Technical Quality         | Resilience                    |
| 174 | Evaluation Research   | Model                   | Technical Quality         | Resilience                    |
| Reference | Type                  | Topic                      | Subtopic                        |
|-----------|-----------------------|----------------------------|---------------------------------|
| 178       | Opinion Paper        | Advice                     | Technical Quality               | Resilience                     |
| 141       | Validation Research  | Theory                     | Technical Quality               | Scalability                    |
| 65        | Evaluation Research  | Model                      | Technical Quality               | Scalability                    |
| 82        | Validation Research  | Advice                     | Technical Quality               | Scalability                    |
| 50        | Validation Research  | Theory                     | Technical Quality               | Scalability                    |
| 37        | Solution Proposal    | Method                     | Technical Quality               | Scalability                    |
| 1123      | Validation Research  | Guideline                  | Technical Quality               | Performance                    |
| 3         | Validation Research  | Lessons Learned            | Technical Quality               | Performance                    |
| 41        | Validation Research  | Method                     | Technical Quality               | Performance                    |
| 179       | Evaluation Research  | Method                     | Technical Quality               | Performance                    |
| 125       | Philosophical Paper  | Method                     | Technical Quality               | Performance                    |
| 126       | Validation Research  | Model                      | Technical Quality               | Performance                    |
| 127       | Philosophical Paper  | Method                     | Technical Quality               | Performance                    |
| 128       | Solution Proposal    | Framework                  | Technical Quality               | Performance                    |
| 109       | Solution Proposal    | Method                     | Technical Quality               | Performance                    |
| 129       | Validation Research  | Tool                       | Technical Quality               | Framework Compliance           |
| 130       | Experience Report    | Method                     | Technical Quality               | Framework Compliance           |
| 131       | Evaluation Research  | Method                     | Technical Quality               | Framework Compliance           |
| 48        | Validation Research  | Theory                     | Governance                      | Regulatory Compliance           |
| 89        | Opinion Paper        | Lessons Learned            | Governance                      | Regulatory Compliance           |
| 55        | Opinion Paper        | Theory                     | Governance                      | Regulatory Compliance           |
| 20        | Philosophical Paper  | Theory                     | Governance                      | Regulatory Compliance           |
| 78        | Evaluation Research  | Lessons Learned            | Governance                      | Regulatory Compliance           |
| 108       | Opinion Paper        | Theory                     | Governance                      | Regulatory Compliance           |
| 80        | Philosophical Paper  | Theory                     | Governance                      | Regulatory Compliance           |
| 55        | Validation Research  | Theory                     | Governance                      | Regulatory Compliance           |
| 69        | Evaluation Research  | Theory                     | Governance                      | Regulatory Compliance           |
| 109       | Solution Proposal    | Method                     | Governance                      | Regulatory Compliance           |
| 112       | Philosophical Paper  | Theory                     | Governance                      | Regulatory Compliance           |
| 72        | Validation Research  | Theory                     | Technical Quality               | Security                        |
| 132       | Philosophical Paper  | Method                     | Technical Quality               | Security                        |
| 64        | Validation Research  | Model                      | Technical Quality               | Security                        |
| 133       | Philosophical Paper  | Theory                     | Technical Quality               | Security                        |
| 79        | Validation Research  | Model                      | Technical Quality               | Extensibility                   |
| 47        | Philosophical Paper  | Method                     | Technical Quality               | Extensibility                   |
| 134       | Experience Report    | Advice                     | Technical Quality               | Test Quality                    |
| 135       | Validation Research  | Theory                     | Technical Quality               | Test Quality                    |
| 138       | Evaluation Research  | Method                     | Technical Quality               | Maintainability                 |
| 136       | Opinion Paper        | Advice                     | Technical Quality               | Maintainability                 |
| 137       | Validation Research  | Lessons Learned            | Technical Quality               | Maintainability                 |
| 139       | Evaluation Research  | Framework                  | Technical Quality               | Maintainability                 |
| 70        | Validation Research  | Lessons Learned            | Technical Quality               | Data-Driven Deployment          |
| 74        | Solution Proposal    | Model                      | Technical Quality               | Data-Driven Deployment          |
| 68        | Solution Proposal    | Framework                  | Technical Quality               | Data-Driven Deployment          |
| 156       | Experience Report    | Process                    | Organization                    | Market Responsiveness           |
| 123       | Validation Research  | Guideline                  | Organization                    | Market Responsiveness           |
| 48        | Validation Research  | Theory                     | Organization                    | Market Responsiveness           |
| 152       | Philosophical Paper  | Theory                     | Organization                    | Market Responsiveness           |
| 49        | Opinion Paper        | Theory                     | Organization                    | Market Responsiveness           |
| 50        | Validation Research  | Theory                     | Organization                    | Market Responsiveness           |
| 157       | Philosophical Paper  | Guideline                  | Organization                    | Market Responsiveness           |
| 72        | Validation Research  | Theory                     | Organization                    | Market Responsiveness           |
| 138       | Validation Research  | Theory                     | Organization                    | Resource Fluidity               |
| 49        | Opinion Paper        | Theory                     | Organization                    | Resource Fluidity               |
| 50        | Validation Research  | Theory                     | Organization                    | Resource Fluidity               |
| ID  | Category            | Type            | Area                      | Context             |
|-----|---------------------|-----------------|---------------------------|---------------------|
| 106 | Opinion Paper      | Guideline       | Organization              | Motivation          |
| 99  | Philosophical Paper| Framework       | Organization              | Motivation          |
| 159 | Philosophical Paper| Theory          | Organization              | Motivation          |
| 89  | Opinion Paper      | Lessons Learned | Organization              | Team-Supplier       |
| 162 | Opinion Paper      | Theory          | Organization              | Team-Supplier       |
| 108 | Opinion Paper      | Theory          | Organization              | Team-Supplier       |
| 160 | Opinion Paper      | Advice          | Organization              | Team-Supplier       |
| 9   | Experience Report  | Lessons Learned | Organization              | Team-Supplier       |
| 56  | Validation Research| Lessons Learned | Organization              | Cross-Team Integration |
| 123 | Validation Research| Guideline       | Organization              | Cross-Team Integration |
| 89  | Opinion Paper      | Lessons Learned | Organization              | Cross-Team Integration |
| 62  | Experience Report  | Lessons Learned | Organization              | Cross-Team Integration |
| 36  | Experience Report  | Advice          | Organization              | Cross-Team Integration |
| 89  | Opinion Paper      | Lessons Learned | Organization              | Cross-Team Integration |
| 136 | Opinion Paper      | Advice          | Organization              | Cross-Team Integration |
| 90  | Validation Research| Theory          | Organization              | Cross-Team Integration |
| 161 | Opinion Paper      | Theory          | Organization              | Cross-Team Integration |
| 148 | Opinion Paper      | Advice          | Organization              | Skills Growth       |
| 9   | Experience Report  | Lessons Learned | Organization              | Skills Growth       |
| 162 | Validation Research| Lessons Learned | Organization              | Skills Growth       |
| 142 | Philosophical Paper| Theory          | Organization              | Skills Growth       |
| 48  | Validation Research| Theory          | Organization              | Skills Growth       |
| 62  | Experience Report  | Lessons Learned | Organization              | Skills Growth       |
| 69  | Validation Research| Lessons Learned | Organization              | Skills Growth       |
| 36  | Experience Report  | Advice          | Business                  | Mean Time To Value  |
| 91  | Experience Report  | Lessons Learned | Business                  | Mean Time To Value  |
| 164 | Opinion Paper      | Advice          | Business                  | Mean Time To Value  |
| 105 | Opinion Paper      | Lessons Learned | Business                  | Costs               |
| 138 | Validation Research| Theory          | Business                  | Costs               |
| 38  | Validation Research| Guideline       | Business                  | Costs               |
| 35  | Validation Research| Theory          | Business                  | Costs               |
| 39  | Validation Research| Model           | Business                  | Costs               |
| 62  | Experience Report  | Lessons Learned | Business                  | Costs               |
| 49  | Opinion Paper      | Theory          | Business                  | Costs               |
| 80  | Philosophical Paper| Theory          | Business                  | Costs               |
| 165 | Philosophical Paper| Theory          | Business                  | Costs               |
| 40  | Evaluation Research| Tool            | Business                  | Ecosystem Valuation |
| 166 | Philosophical Paper| Theory          | Business                  | Ecosystem Valuation |
| 89  | Opinion Paper      | Lessons Learned | Business                  | Ecosystem Valuation |
| 162 | Opinion Paper      | Theory          | Business                  | Ecosystem Valuation |
| 138 | Evaluation Research| Method          | Business                  | Ecosystem Valuation |
| 167 | Evaluation Research| Framework       | Business                  | Ecosystem Valuation |
| 155 | Philosophical Paper| Theory          | Business                  | Ecosystem Valuation |
| 69  | Evaluation Research| Theory          | Business                  | Ecosystem Valuation |
| 66  | Validation Research| Model           | Business                  | Ecosystem Valuation |
| 168 | Opinion Paper      | Theory          | Business                  | Product Market Share|
| 47  | Evaluation Research| Guideline       | Business                  | Product Market Share|
| 86  | Opinion Paper      | Guideline       | Business                  | Product Market Share|
| 162 | Opinion Paper      | Theory          | Business                  | Product Market Share|
| 136 | Opinion Paper      | Advice          | Business                  | Product Market Share|
Table 14: Systematic map overview.

Bibliography

[1] Philipp Haindl and Reinhold Plösch. “Focus Areas, Themes, and Objectives of Non-Functional Requirements in DevOps: A Systematic Mapping Study”. In: 2020 46th Euromicro Conference on Software Engineering and Advanced Applications (SEAA). 2020, pp. 394–403. DOI: 10.1109/SEAA51224.2020.00071

[2] L. Chung et al. Non-Functional Requirements in Software Engineering. Vol. 5. International Series in Software Engineering. Springer US, 2000. ISBN: 978-0-7923-8666-7.

[3] Lawrence Chung and Julio Cesar Prado Leite. “On Non-Functional Requirements in Software Engineering”. In: c. Berlin, Heidelberg: Springer, 2009, pp. 363–379. ISBN: 978-3-642-02462-7.

[4] Maya Daneva, Luigi Buglione, and Andrea Herrmann. “Software Architects’ Experiences of Quality Requirements: What We Know and What We Do Not Know?”. In: Requirements Engineering: Foundation for Software Quality. Ed. by Joerg Doerr and Andreas L. Opdahl. Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2013, pp. 1–17. ISBN: 978-3-642-37422-7.

[5] J. Doerr et al. “Non-functional requirements in industry - three case studies adopting an experience-based NFR method”. In: 13th IEEE International Conference on Requirements Engineering (RE’05). 2005, pp. 373–382. DOI: 10.1109/RE.2005.47

[6] Volker Gruhn and Clemens Schäfer. “BizDevOps: Because DevOps is Not the End of the Story”. In: Intelligent Software Methodologies, Tools and Techniques. Ed. by Hamido Fujita and Guido Guizzi. Communications in Computer and Information Science. Springer International Publishing, 2015, pp. 388–398. ISBN: 978-3-319-22689-7.

[7] Peter Forbrig and Anke Dittmar. “Integrating HCD into BizDevOps by Using the Subject-Oriented Approach”. In: Human-Centered Software Engineering. Ed. by Cristian Bogdan et al. Lecture Notes in Computer Science. Springer International Publishing, 2019, pp. 327–334. ISBN: 978-3-030-05909-5.

[8] Ramtin Jabbari et al. “What is DevOps?: A Systematic Mapping Study on Definitions and Practices”. In: ACM, 2016, p. 12. ISBN: 978-1-4503-4134-9. DOI: 10.1145/2962695.2962707

[9] Mali Senapathi, Jim Buchan, and Hady Osman. “DevOps Capabilities, Practices, and Challenges: Insights from a Case Study”. In: Proceedings of the 22Nd International Conference on Evaluation and Assessment in Software Engineering 2018. EASE’18. New York, NY, USA: ACM, 2018, pp. 57–67. ISBN: 978-1-4503-6403-4. DOI: 10.1145/3210459.3210465

[10] Erik Beulen. “Implementing and Contracting Agile and DevOps: A Survey in the Netherlands”. In: Digital Services and Platforms. Considerations for Sourcing. Springer, Cham, 2018, pp. 124–146. DOI: 10.1007/978-3-030-15850-7_7

[11] Aymeric Hemon et al. “From Agile to DevOps: Smart Skills and Collaborations”. In: Information Systems Frontiers (2019), pp. 1–19. DOI: 10.1007/s10796-019-09905-1

[12] Len Bass, Ingo Weber, and Liming Zhu. DevOps: A Software Architect’s Perspective. English. 1 edition. New York: Addison-Wesley Professional, 2015. ISBN: 978-0-13-404984-7.

[13] D. A. Tamburri, R. Kazman, and H. Fahimi. “The Architect’s Role in Community Shepherding”. In: IEEE Software 33.06 (2016), pp. 70–79. DOI: 10.1109/MS.2016.144.
Non-Functional Requirements in DevOps: A Systematic Mapping Study

[14] Peter Freeman. *Software Perspectives: The System is the Message*. Boston, MA, USA: Addison-Wesley Longman Publishing Co., Inc., 1987. ISBN: 978-0-201-11969-5.

[15] Y. Liu, Z. Ma, and W. Shao. “Integrating Non-functional Requirement Modeling into Model Driven Development Method”. In: *2010 Asia Pacific Software Engineering Conference*. 2010, pp. 98–107. DOI: 10.1109/APSEC 2010.21

[16] M. Broy. “Rethinking Nonfunctional Software Requirements”. In: *Computer* 48.5 (2015), pp. 96–99. DOI: 10.1109/TC.2015.139

[17] J. Eckhardt, A. Vogelsang, and D. M. Fernández. “Are "Non-functional" Requirements really Non-functional? An Investigation of Non-functional Requirements in Practice”. In: *2016 IEEE/ACM 38th International Conference on Software Engineering (ICSE)*. 2016, pp. 832–842. DOI: 10.1109/ICSE.2016.2884781.2884788

[18] D. Ameller, X. Franch, and J. Cabot. “Dealing with Non-Functional Requirements in Model-Driven Development”. In: *2010 18th IEEE International Requirements Engineering Conference*. 2010, pp. 189–198. DOI: 10.1109/RE.2010.32

[19] H. Hiisilä and M. Kujala. “Combining Process Modeling and Requirements Engineering: An Experience Report”. In: *2015 IEEE 17th Conference on Business Informatics*. Vol. 1. 2015, pp. 242–249. DOI: 10.1109/CBI.2015.20

[20] M. Glinz. “On Non-Functional Requirements”. In: *15th IEEE International Requirements Engineering Conference (RE) 2007*. 2007, pp. 21–26. DOI: 10.1109/RE.2007.45

[21] Dewi Mairiza, Didar Zowghi, and Nurie Nurmuliani. “An Investigation into the Notion of Non-functional Requirements”. In: * Enterprise, Business-Process and Information Systems Modeling*. Ed. by Ilia Bider et al. Lecture Notes in Business Information Processing. Springer Berlin Heidelberg, 2014, pp. 348–362. ISBN: 978-3-662-43745-2.

[22] S. Ouhbi et al. “Software Quality Requirements: A Systematic Mapping Study”. In: *2013 20th Asia-Pacific Software Engineering Conference (APSEC)*. Vol. 1. 2013, pp. 231–238. DOI: 10.1109/APSEC.2013.40

[23] Leah Ruungu-Kalliossaari et al. “DevOps Adoption Benefits and Challenges in Practice: A Case Study”. In: *Product-Focused Software Process Improvement*. Ed. by Pekka Abrahamsson et al. Lecture Notes in Computer Science. Springer International Publishing, 2016, pp. 590–597. ISBN: 978-3-319-49094-6.

[24] Barbara A. Kitchenham, David Budgen, and O. Pearl Brereton. “Using Mapping Studies As the Basis for Further Research - A Participant-observer Case Study”. In: *Inf. Softw. Technol.* 53.6 (2011), pp. 638–651. DOI: 10.1016/j.infsof.2010.12.011 URL: http://dx.doi.org/10.1016/j.infsof.2010.12.011

[25] Claes Wohlin. “Guidelines for Snowballing in Systematic Literature Studies and a Replication in Software Engineering”. In: *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*. EASE ’14. event-place: London, England, United Kingdom. New York, NY, USA: ACM, 2014, 38:1–38:10. ISBN: 978-1-4503-2476-2. DOI: 10.1145/2601248.2601268

[26] Kai Petersen et al. “Systematic mapping studies in software engineering”. In: *EASE’08 Proceedings of the 12th international conference on Evaluation and Assessment in Software Engineering*. 2008, pp. 68–77.

[27] Philipp Haindl and Reinhold Plösch. “Towards Continuous Quality: Measuring and Evaluating Feature-Dependent Non-Functional Requirements in DevOps”. In: *2019 IEEE International Conference on Software Architecture Companion (ICSA-C)*. 2019, pp. 91–94. DOI: 10.1109/ICSA-C.2019.00024

[28] Philipp Haindl, Reinhold Plösch, and Christian Körner. “An Extension of the QUAMOCO Quality Model to Specify and Evaluate Feature-Dependent Non-Functional Requirements”. In: *2019 45th Euromicro Conference on Software Engineering and Advanced Applications (SEAA)*. 2019, pp. 19–28. DOI: 10.1109/SEAA.2019.00012

[29] Barbara Kitchenham and Stuart Charters. *Guidelines for performing systematic literature reviews in software engineering*. Technical report EBSE-2007-01. 2007.

[30] Roel Wieringa et al. “Requirements Engineering Paper Classification and Evaluation Criteria: A Proposal and a Discussion”. In: *Requir. Eng.* 11.1 (2005), pp. 102–107. DOI: 10.1007/s00766-005-0021-6 URL: http://dx.doi.org/10.1007/s00766-005-0021-6

[31] M. Shaw. “Writing good software engineering research papers”. In: *25th International Conference on Software Engineering*. 2003. Proceedings. 2003, pp. 726–736. DOI: 10.1109/ICSE.2003.1201262

[32] Nicolò Paternoster et al. “Software development in startup companies: A systematic mapping study”. In: *Information and Software Technology* 56.10 (2014), pp. 1200–1218. DOI: 10.1016/j.infsof.2014.04.014
[34] D. S. Cruzes and T. Dyba. “Recommended Steps for Thematic Synthesis in Software Engineering”. In: *2011 International Symposium on Empirical Software Engineering and Measurement*. 2011, pp. 275–284. DOI: 10.1109/ESEM.2011.36

[35] Norman Riegel and Joerg Doerr. “A Systematic Literature Review of Requirements Prioritization Criteria”. en. In: *Requirements Engineering: Foundation for Software Quality*. Springer, Cham, 2015, pp. 300–317. DOI: 10.1007/978-3-319-16101-3_22

[36] E. Dörnenburg. “The Path to DevOps”. In: *IEEE Software* 35.5 (2018), pp. 71–75. DOI: 10.1109/MS.2018290110337

[37] M. Saadatmand, A. Cicchetti, and M. Sjödin. “Toward Model-Based Trade-off Analysis of Non-functional Requirements”. In: *2012 38th Euromicro Conference on Software Engineering and Advanced Applications*. 2012, pp. 142–149. DOI: 10.1109/SEAA.2012.23

[38] Elisabetta Di Nitto et al. “A software architecture framework for quality-aware DevOps”. In: ACM, 2016, pp. 12–17. ISBN: 978-1-4503-4411-1. DOI: 10.1145/2945408.2945411

[39] Jaakko Aspara and Henriikki Tikkanen. “Creating novel consumer value vs. capturing value: Strategic emphases and financial performance implications”. In: *Journal of Business Research* 66.5 (2013), pp. 593–602. DOI: 10.1016/j.jbusres.2012.04.004

[40] Luciana A. Almeida et al. “Assessing the Value Blueprint to Support the Design of a Business Ecosystem”, en. In: *Software Business*. Ed. by João M. Fernandes, Ricardo J. Machado, and Krzysztof Wnuk. Lecture Notes in Business Information Processing. Springer International Publishing, 2015, pp. 96–101. ISBN: 978-3-319-19593-3

[41] J. Cleland-Huang et al. “Goal-centric traceability for managing non-functional requirements”. In: *Proceedings. 27th International Conference on Software Engineering*. 2005. ICSE 2005. 2005, pp. 362–371. DOI: 10.1109/ICSE.2005.1553579

[42] Jens Smeds, Kristian Nyborn, and Ivan Porres. “DevOps: A Definition and Perceived Adoption Impediments”. en. In: *Agile Processes in Software Engineering and Extreme Programming*. Springer, Cham, 2015, pp. 166–177. DOI: 10.1007/978-3-319-18612-2_14

[43] C. Ebert et al. “DevOps”. In: *IEEE Software* 33.3 (2016), pp. 94–100.

[44] Silverio Martínez-Fernández et al. “Towards Automated Data Integration in Software Analytics”. In: *Proceedings of the International Workshop on Real-Time Business Intelligence and Analytics*. BIRTE ’18. New York, NY, USA: ACM, 2018, 6:1–6.5. ISBN: 978-1-4503-6607-6. DOI: 10.1145/3242153.3242159

[45] Mojtaba Shahin et al. “Beyond continuous delivery: an empirical investigation of continuous deployment challenges”. In: IEEE Press, 2017, pp. 111–120. ISBN: 978-1-5090-4039-1. DOI: 10.1109/ESEM.2017.18

[46] “ISO/IEC/IEEE 25010:2011 International Standard - Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models”. In: 25010 (2018), (accessed 2022/01/15). URL: https://www.iso.org/standard/35733.html

[47] H. Yang et al. “Linking Functions and Quality Attributes for Software Evolution”. In: *2012 19th Asia-Pacific Software Engineering Conference*. Vol. 1. 2012, pp. 250–259. DOI: 10.1109/APSEC.2012.151

[48] Kim Dikert, Maria Paasivaara, and Casper Lassenius. “Challenges and success factors for large-scale agile transformations: A systematic literature review”. In: *Journal of Systems and Software* 119 (2016), pp. 87–108. DOI: 10.1016/j.jss.2016.06.013

[49] Maarit Laanti. “Characteristics and Principles of Scaled Agile”. en. In: *Agile Methods. Large-Scale Development, Refactoring, Testing, and Estimation*. Springer, Cham, 2014, pp. 9–20. DOI: 10.1007/978-3-319-14358-3_2

[50] Abheeshta Putta, Maria Paasivaara, and Casper Lassenius. “Benefits and Challenges of Adopting the Scaled Agile Framework (SAFe): Preliminary Results from a Multivocal Literature Review”. en. In: *Product-Focused Software Process Improvement*. Springer, Cham, 2018, pp. 334–351. DOI: 10.1007/978-3-030-03673-7_24

[51] Gérson Tontini. *Integrating the Kano Model and QFD for Designing New Products*. Vol. 18. 2007. DOI: 10.1080/14783360701349351

[52] Ries Eric. *The Lean Startup: How Today’s Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. Currency, 2017. ISBN: 978-1-5247-6240-7.

[53] Alexander Osterwalder and Yves Pigneur. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. English. 1st edition. Hoboken, NJ: John Wiley and Sons, 2010. ISBN: 978-0-470-87641-1.

[54] Bernd Wirtz. *Business Model Management: Design - Instruments - Success Factors*. 2011. ISBN: 978-3-8349-2792-7.
Non-Functional Requirements in DevOps: A Systematic Mapping Study

[55] S. Fricker. “Software Product Management”. In: Software for People. Ed. by A. Maedche, A. Botzenhardt, and L. Neer. Springer, 2012, pp. 53–81. ISBN: 978-3-642-31370-7.

[56] Barry Boehm and Li Guo Huang. “Value-based software engineering: a case study”. In: Computer 36.3 (2003), pp. 33–41. DOI: 10.1109/MC.2003.1185215.

[57] M. Kersten. “What Flows through a Software Value Stream?” In: IEEE Software 35.4 (2018), pp. 8–11. DOI: 10.1109/M.2018.2801538.

[58] Eetu Luoma, Mikko Rönkkö, and Pasi Tyrväinen. “Current Software-as-a-Service Business Models: Evidence from Finland”. In: Software Business. Ed. by Michael A. Cusumano, Bala Iyer, and N. Venkatraman. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 181–194. ISBN: 978-3-642-30746-1.

[59] Elizabeth Bjarnason et al. “Challenges and practices in aligning requirements with verification and validation: a case study of six companies”. In: Empirical Software Engineering 19.6 (2014), pp. 1809–1855. DOI: 10.1007/s10664-013-9263-y. URL: https://doi.org/10.1007/s10664-013-9263-y.

[60] Jan Bosch and Petra Bosch-Sijtsema. “ESAO: A Holistic Ecosystem-Driven Analysis Model”. In: Software Business. Towards Continuous Value Delivery. Ed. by Casper Lassenius and Kari S몰ander. Springer International Publishing, 2014, pp. 179–193. ISBN: 978-3-319-08738-2.

[61] Fogelström Dzamashvili et al. “The impact of agile principles on market-driven software product development”. In: Journal of Software Maintenance and Evolution: Research and Practice 22.1 (2010), pp. 53–80. DOI: 10.1002/spip.420. URL: http://dx.doi.org/10.1002/spip.420.

[62] F. A. Erich, C. Amrit, and M. Daneva. “A qualitative study of DevOps usage in practice”. en. In: Journal of Software: Evolution and Process 29.6 (2017), e1885. DOI: 10.1002/smr.1885.

[63] Aleksander Fabijan, Helena Holmström Olsson, and Jan Bosch. “Early Value Argumentation and Prediction: An Iterative Approach to Quantifying Feature Value”. In: Product-Focused Software Process Improvement. Ed. by Pekka Abrahamsson et al. Springer International Publishing, 2015, pp. 16–23. ISBN: 978-3-319-26844-6.

[64] A. Fabijan, H. H. Olsson, and J. Bosch. “Customer Feedback and Data Collection Techniques in Software R&D: A Literature Review”. In: Software Business. Ed. by J. M. Fernandes, R. J. Machado, and K. Wnuk. Springer, 2015, pp. 139–153. ISBN: 978-3-319-19593-3.

[65] F. Fagerholm et al. “Building blocks for continuous experimentation”. In: RCoSE 2014 Proceedings of the 1st International Workshop on Rapid Continuous Software Engineering. Hyderabad, India, 2014, pp. 26–35. ISBN: 978-1-4503-2856-2.

[66] F. Fagerholm et al. “The RIGHT model for Continuous Experimentation”. In: Journal of Systems and Software 123 (2017), pp. 292–305. DOI: 10.1016/j.jss.2016.03.034.

[67] Nicole Forsgren, Jez Humble, and Gene Kim. “Components of Lean Product Management”. English. In: Accelerate: The Science of Lean Software and DevOps: Building and Scaling High Performing Technology Organizations. 1st ed. Portland, Oregon: IT Revolution Press, 2018. ISBN: 978-1-942788-33-1.

[68] Helena Holmström Olsson and Jan Bosch. “Towards Continuous Customer Validation: A Conceptual Model for Combining Qualitative Customer Feedback with Quantitative Customer Observation”. en. In: Software Business. Ed. by Joao M. Fernandes, Ricardo J. Machado, and Krzysztof Wnuk. Lecture Notes in Business Information Processing. Springer International Publishing, 2015, pp. 154–166. ISBN: 978-3-319-19593-3.

[69] Pilar Rodríguez et al. “Continuous deployment of software intensive products and services: A systematic mapping study”. In: Journal of Systems and Software 123 (2017), pp. 263–291. DOI: 10.1016/j.jss.2015.12.015.

[70] T. Sauvola et al. “Towards Customer-Centric Software Development: A Multiple-Case Study” In: 2015 41st Euromicro Conference on Software Engineering and Advanced Applications. 2015, pp. 9–17. DOI: 10.1109/SEAA.2015.63.

[71] Erno Vanhala and Jussi Kasurinen. “The Role of Business Model and Its Elements in Computer Game Start-ups”. en. In: Software Business. Towards Continuous Value Delivery. Ed. by Casper Lassenius and Kari Smolander. Lecture Notes in Business Information Processing. Springer International Publishing, 2014, pp. 72–87. ISBN: 978-3-319-08738-2.

[72] Sezin Gizem Yaman et al. “Customer Involvement in Continuous Deployment: A Systematic Literature Review”. en. In: Requirements Engineering: Foundation for Software Quality. Ed. by Maya Daneva and Oscar Pastor. Lecture Notes in Computer Science. Springer International Publishing, 2016, pp. 249–265. ISBN: 978-3-319-30282-9.

[73] L. Cao and B. Ramesh. “Agile Requirements Engineering Practices: An Empirical Study”. In: IEEE Software 25.1 (2008), pp. 60–67. DOI: 10.1109/M.2008.1.
[74] Helena Holmström Olsson and Jan Bosch. “From Requirements to Continuous Re-prioritization of Hypotheses”. In: 2016 IEEE/ACM International Workshop on Continuous Software Evolution and Delivery (CSED). 2016, pp. 63–69. DOI: 10.1109/CSED.2016.020

[75] A. B. Carrillo, P. R. Mateo, and M. R. Monje. “Metrics to evaluate functional quality: A systematic review”. In: IEEE, 2012, pp. 1–6. ISBN: 2166-0727.

[76] Alexey Drutsa, Anna Ufliand, and Gleb Gusev. “Practical Aspects of Sensitivity in Online Experimentation with User Engagement Metrics”. In: CIKM ’15 Proceedings of the 24th ACM International on Conference on Information and Knowledge Management. Melbourne, Australia, 2015. DOI: 10.1145/2806416.2806496

[77] Feihua Huang. “Technology innovation and new product development process integrating QFD and TRIZ”. In: 2013 Sichuan-Silicon Valley-Beijing International Innovation Conference. 2013, pp. 127–131. DOI: 10.1109/STIC.2013.6624179

[78] K. Kevic et al. “Characterizing Experimentation in Continuous Deployment: A Case Study on Bing”. In: 2017, pp. 123–132. DOI: 10.1109/ICSE-SEIP.2017.19.

[79] K. Mehmood and S. S. Cherfi. “Evaluating the Functionality of Conceptual Models”. In: Advances in Conceptual Modeling - Challenging Perspectives. Ed. by C. A. Heuser and G. Pernul. Berlin, Germany: Springer, 2009, pp. 222–231. ISBN: 978-3-642-04947-7.

[80] Geoffrey P. Parker, Marshall W. van Alstyne, and Sangeet Paul Choudary. Platform Revolution: How Networked Markets Are Transforming and How to Make Them Work for You: How Networked Markets Are Transforming. Englisch. Reprint. New York London: Norton & Company, 2017. ISBN: 978-0-393-35435-5.

[81] Moisés Rodríguez, Jesús Ramón Oviedo, and Mario Piattini. “Evaluation of Software Product Functional Suitability: A Case Study”. In: Software Quality Professional 18.3 (2016), pp. 18–29.

[82] Torgeir Dingsøyr et al. “Exploring software development at the very large-scale: a revelatory case study and research agenda for agile method adaptation”. In: Empirical Software Engineering 23.1 (2018), pp. 490–520. DOI: 10.1007/s10664-017-9524-2 URL: https://doi.org/10.1007/s10664-017-9524-2

[83] John Favaro. “Managing Requirements for Business Value”. In: IEEE Softw. 19.2 (2002), pp. 15–17. DOI: 10.1109/52.991325 URL: https://doi.org/10.1109/52.991325

[84] S. Martínez-Fernández et al. “A Quality Model for Actionable Analytics in Rapid Software Development”. In: 2018 44th Euromicro Conference on Software Engineering and Advanced Applications (SEAA). 2018, pp. 370–377. DOI: 10.1109/SEAA.2018.00067.

[85] Jarno Vähäniitty and Kristian Rautiainen. “Towards a conceptual framework and tool support for linking long-term product and business planning with agile software development”. In: SDG ’08 Proceedings of the 1st International Workshop on Software Development Governance. Leipzig, Germany: ACM New York, 2008, pp. 25–28.

[86] Nicole Forsgren and Mik Kersten. “DevOps Metrics”. In: ACM Queue 15.6 (2018), pp. 1–16.

[87] M. Kersten. “Mining the Ground Truth of Enterprise Toolchains”. In: IEEE Software 35.3 (2018), pp. 12–17. DOI: 10.1109/MS.2018.2141029.

[88] Enrique Larios Vargas et al. “Enabling Real-time Feedback in Software Engineering”. In: Proceedings of the 40th International Conference on Software Engineering: New Ideas and Emerging Results. ICSE-NIER ’18. New York, NY, USA: ACM, 2018, pp. 21–24. ISBN: 978-1-4503-5662-6. DOI: 10.1145/3183399.3183416

[89] C. Ebert and M. Paasivaara. “Scaling Agile”. In: IEEE Software 34.6 (2017), pp. 98–103. DOI: 10.1109/MS.2017.4121226

[90] Nicole Forsgren, Jez Humble, and Gene Kim. “Software Delivery Performance”. English. In: Accelerate: The Science of Lean Software and DevOps: Building and Scaling High Performing Technology Organizations. 1st ed. Portland, Oregon: IT Revolution Press, 2018. ISBN: 978-1-942788-33-1.

[91] Harald Gall et al. “Software Development Analytics (Dagstuhl Seminar 14261)”. In: Dagstuhl Reports 4.6 (2014). Ed. by Harald Gall et al., pp. 64–83. DOI: 10.4230/DagRep.4.6.64 URL: http://drops.dagstuhl.de/opus/volltexte/2014/4763

[92] Lena Karlsson et al. “Requirements engineering challenges in market-driven software development – An interview study with practitioners”. In: Qualitative Software Engineering Research 49.6 (2007), pp. 588–604. DOI: 10.11016/j.infsof.2007.02.008

[93] Sylwia Kopczyńska, Jerzy Nawrocki, and Miroslaw Ochodek. “An empirical study on catalog of non-functional requirement templates: Usefulness and maintenance issues”. en. In: Information and Software Technology 103 (2018), pp. 75–91. DOI: 10.11016/j.infsof.2018.06.009

[94] Jürgen Cito et al. “Context-based analytics: establishing explicit links between runtime traces and source code”. In: IEEE Press, 2017, pp. 193–202. ISBN: 978-1-5386-2717-4. DOI: 10.1109/ICSE-SEIP.2017.1
[95] X. Lian, J. Cleland-Huang, and L. Zhang. “Mining Associations Between Quality Concerns and Functional Requirements”. In: 2017 IEEE 25th International Requirements Engineering Conference (RE). 2017, pp. 292–301. DOI: [10.1109/RE.2017.68]

[96] N. Niu et al. “Requirements Engineering and Continuous Deployment”. In: IEEE Software 35.2 (2018), pp. 86–90. DOI: [10.1109/MS.2018.1661352]

[97] Liliana Guzmán et al. “How Can Quality Awareness Support Rapid Software Development? – A Research Preview”, en. In: Requirements Engineering: Foundation for Software Quality. Ed. by Paul Grünbacher and Anna Perini. Lecture Notes in Computer Science. Springer International Publishing, 2017, pp. 167–173. ISBN: 978-3-319-54045-0.

[98] M. Haleem and M. R. Beg. “Impact analysis of requirement metrics in software development environment”. In: 2015 IEEE International Conference on Electrical, Computer and Communication Technologies. 2015, pp. 1–6. DOI: [10.1007/978-3-030-03673-7_4]

[99] Petra Bosch-Sijtsema and Jan Bosch. “User Involvement throughout the Innovation Process in High-Tech Industries”. In: Journal of Product Innovation Management 32.5 (2015), pp. 793–807. DOI: [10.1111/jpim.12233] URL: [http://dx.doi.org/10.1111/jpim.12233]

[100] Xavier Franch et al. “Data-Driven Elicitation, Assessment and Documentation of Quality Requirements in Agile Software Development”. en. In: Advanced Information Systems Engineering. Ed. by John Krogstie and Hajo A. Reijers. Lecture Notes in Computer Science. Springer International Publishing, 2018, pp. 587–602. ISBN: 978-3-319-91563-0.

[101] Vitalii Ivanov and Kari Smolander. “Implementation of a DevOps Pipeline for Serverless Applications”, en. In: Product-Focused Software Process Improvement. Springer, Cham, 2018, pp. 48–64. DOI: [10.1007/978-3-030-03673-7_4]

[102] William Robinson. “A Roadmap for Comprehensive Requirements Modeling”. In: Computer 43.5 (2010), pp. 64–72.

[103] Tejas Shah and S V Patel. “A Novel Approach for Specifying Functional and Non-functional Requirements Using RDS (Requirement Description Schema)”. en. In: Procedia Computer Science 79 (2016), pp. 852–860. DOI: [10.1016/j.procs.2016.03.083]

[104] Michael Vierhauser, Rick Rabiser, and Paul Grünbacher. “Requirements monitoring frameworks: A systematic review”. In: Information and Software Technology 80 (2016), pp. 89–109. DOI: [https://doi.org/10.1016/j.infsof.2016.08.005]

[105] Ron Adner. The Wide Lens: What Successful Innovators See That Others Miss. Englisch. Updated. New York, New York: Portfolio, 2013. ISBN: 978-1-59184-629-1.

[106] Kevin Boudreau and Karim Lakhani. “How to Manage Outside Innovation”. In: MIT Sloan Management Review 50.4 (2009), pp. 69–76.

[107] Racim Fahssi, Célia Martinie, and Philippe Palanque. “Enhanced Task Modelling for Systematic Identification and Explicit Representation of Human Errors”. In: Human-Computer Interaction – INTERACT 2015. Ed. by Julio Abascal et al. Bamberg, Germany: Springer International Publishing, 2015, pp. 192–212. ISBN: 978-3-319-22723-8.

[108] Hans-Bernd Kittlaus. “Software Product Management and Agile Software Development: Conflicts and Solutions”. In: Software for People. Ed. by Alexander Maedche, Achim Botzenhardt, and Ludwig Neer. Springer Heidelberg, 2012, pp. 83–96. ISBN: 978-3-642-31370-7.

[109] B. Schmelting et al. “Composing Non-functional Concerns in Web Services”. In: 2011 IEEE Ninth European Conference on Web Services. 2011, pp. 73–80. DOI: [10.1109/ECOWS.2011.25]

[110] Paul Timmers. “Business Models for Electronic Markets”. In: Electronic Markets 8.2 (1998), pp. 3–8. DOI: [10.1080/10196789880000016]

[111] Yong Zhang, Miner Zhong, and Yunjian Jiang. “A data-driven quantitative assessment model for taxi industry: the scope of business ecosystem’s health”. In: European Transport Research Review 9.2 (2017), p. 23. DOI: [10.1007/s12544-017-0241-0] URL: [https://doi.org/10.1007/s12544-017-0241-0]

[112] Didar Zowghi and Chad Coulin. “Requirements Elicitation: A Survey of Techniques, Approaches, and Tools”. In: Engineering and Managing Software Requirements. Ed. by Abyüke Aurum and Claes Wohlin. Berlin, Heidelberg: Springer Berlin Heidelberg, 2005, pp. 19–46. ISBN: 978-3-540-28244-0. DOI: [10.1007/3-540-28244-0_2]

[113] Albert Fleischmann et al. “Coherent Task Modeling and Execution Based on Subject-Oriented Representations”. In: Task Models and Diagrams for User Interface Design. Ed. by David England et al. Brussels, Belgium: Springer Berlin Heidelberg, 2010, pp. 78–91. ISBN: 978-3-642-11797-8.
[114] Eric-Oluf Svee, Jelena Zdravkovic, and Constantinios Giannoulis. “Consumer Value-Aware Enterprise Archi-
tecture”. en. In: Software Business. Ed. by Michael A. Cusumano, Bala Iyer, and N. Venkatraman. Lecture Notes
in Business Information Processing. Springer Berlin Heidelberg, 2012, pp. 55–69. ISBN: 978-3-642-30746-1.

[115] Andrea Urbini et al. “The role of digital technologies in open innovation processes: an exploratory multiple
study case analysis”. In: R&D Management (2018). DOI: 10.1111/radm.12313 URL: http://dx.doi
.org/10.1111/radm.12313

[116] Van Haren. TOGAF Version 9.1. 10th. Van Haren Publishing, 2011. ISBN: 978-90-8753-679-4.

[117] Rick Kazman, Mark Klein, and Paul Clements. ATAM: Method for Architecture Evaluation. Tech. rep. CMU/SEI-
2000-TR-004. Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2000. URL: http://
resources.sei.cmu.edu/library/asset-view.cfm?AssetID=5177

[118] Juan Gonzalez Calleros and Josefina Guerrero. “Towards a Multi-User Interaction Meta-Model”. In:
Romanian Journal of Human-Computer Interaction 7.2 (2014), pp. 93–116.

[119] David Navarre et al. “ICOs: A model-based user interface description technique dedicated to interactive systems
addressing usability, reliability and scalability”. In: ACM Transactions on Computer-Human Interaction
(TOCHI) 16.4 (2009). DOI: 10.1145/1614390.1614393

[120] C. Rich. “Building Task-Based User Interfaces with ANSI/CEA-2018”. In: Computer 42.8 (2009), pp. 20–27.
DOI: 10.1109/MC.2009.247

[121] Isaac Griffith, Clemente Izurieta, and Chris Huvaere. “An Industry Perspective to Comparing the SQALE
and Quamoco Software Quality Models”. In: Proceedings of the 11th ACM/IEEE International Symposium
on Empirical Software Engineering and Measurement. ESEM ’17. Piscataway, NJ, USA: IEEE Press, 2017,
pp. 287–296. ISBN: 978-1-5090-4039-1. DOI: 10.1109/ESEM.2017.42

[122] A. van Lamsweerde and E. Letier. “Handling obstacles in goal-oriented requirements engineering”. In: IEEE
Transactions on Software Engineering 26.10 (2000), pp. 978–1005. DOI: 10.1109/32.879820.

[123] Jan Bosch and Petra M. Bosch-Sijtsesma. “Introducing agile customer-centered development in a legacy software
product line”. In: Software: Practice and Experience 41.8 (2011), pp. 871–882. DOI: 10.1002/spe.1063
URL: http://dx.doi.org/10.1002/spe.1063

[124] Peter Forbrig et al. “Rapid Task-Models Development Using Sub-models, Sub-routines and Generic Compo-
nents”. In: Human-Centered Software Engineering. Ed. by Stefan Sauer et al. Paderborn, Germany: Springer
Berlin Heidelberg, 2014, pp. 144–163. ISBN: 978-3-662-44811-3.

[125] M. Glinz. “A Risk-Based, Value-Oriented Approach to Quality Requirements”. In: IEEE Software 25.2 (2008),
pp. 34–41. DOI: 10.1109/MCS.2008.31

[126] M Kläs et al. “CQML Scheme: A Classification Scheme for Comprehensive Quality Model Landscapes”. In:
2009, pp. 243–250. DOI: 10.1109/SEAA.2009.88

[127] Yuumu Matsumotoa, Sayaka Shiraia, and Atsushi Ohnishiia. “A Method for Verifying Non-Functional Require-
ments”. en. In: Procedia Computer Science 112 (2017), pp. 157–166. DOI: 10.1016/j.procs.2017.08.006

[128] William N. Robinson. “A requirements monitoring framework for enterprise systems”. In: Requirements
Engineering 11.1 (2006), pp. 17–41. DOI: 10.1007/s00766-005-0016-3 URL: https://doi.org/10
.1007/s00766-005-0016-3

[129] G. Hecht et al. “Tracking the Software Quality of Android Applications Along Their Evolution (T)”. In: 2015
30th IEEE/ACM International Conference on Automated Software Engineering (ASE). 2015, pp. 236–247.
DOI: 10.1109/ASE.2015.46

[130] H. Kaiya and A. Ohnishi. “Quality Requirements Analysis Using Requirements Frames”. In: 2011 11th Inter-
national Conference on Quality Software. 2011, pp. 198–207. DOI: 10.1109/QSIC.2011.21

[131] Plösch, Reinhold and Mayr, Alois and Köner, Christian. “Collecting Quality Requirements Using Quality Mod-
els and Goals”. In: 2010 Seventh International Conference on the Quality of Information and Communications
Technology. 2010, pp. 198–203. DOI: 10.1109/QUATIC.2010.42

[132] J. Eckhardt, D. Mendez Fernandez, and A. Vogelsang. “How to Specify Non-Functional Requirements to
Support Seamless Modeling? A Study Design and Preliminary Results”. In: 2015 ACM/IEEE International
Symposium on Empirical Software Engineering and Measurement (ESEM). 2015, pp. 1–4. DOI: 10.1109/
ESEM.2015.7321200

[133] Markus Schief. Business Models in the Software Industry: The Impact on Firm and M&A Performance. en.
Gabler Verlag, 2014. ISBN: 978-3-658-04351-3.

[134] Andrew Begel and Thomas Zimmermann. “Analyze This! 145 Questions for Data Scientists in Software
Engineering”. In: Proceedings of the 36th International Conference on Software Engineering. ICSE 2014. New
York, NY, USA: ACM, 2014, pp. 12–23. ISBN: 978-1-4503-2756-5. DOI: 10.1145/2568225.2568233
Non-Functional Requirements in DevOps: A Systematic Mapping Study

[135] Qibo Yang, Jin Tian, and Tingdi Zhao. “Safety is an emergent property: Illustrating functional resonance in Air Traffic Management with formal verification”. In: Safety Science 93 (2017), pp. 162–177. DOI: [10.1016/j.ssci.2016.12.006](https://doi.org/10.1016/j.ssci.2016.12.006)

[136] Bosch J. “Speed, Data, and Ecosystems: The Future of Software Engineering”. In: IEEE Software 33.1 (2016), pp. 82–88. DOI: [10.1109/MS.2016.14](https://doi.org/10.1109/MS.2016.14)

[137] Klaus Lochmann, Jasmin Ramadani, and Stefan Wagner. “Are Comprehensive Quality Models Necessary for Evaluating Software Quality?” In: Proceedings of the 9th International Conference on Predictive Models in Software Engineering. PROMISE '13. New York, NY, USA: ACM, 2013, 3:1–3:9. ISBN: 978-1-4503-2016-0. DOI: [10.1145/2499393.2499404](https://doi.org/10.1145/2499393.2499404)

[138] Helena Olsson Holmström and Jan Bosch. “From ad hoc to strategic ecosystem management: the “Three-Layer Ecosystem Strategy Model” (TeLESM)”. In: Journal of Software: Evolution and Process 29.7 (2017). DOI: [10.1002/smr.1876](https://doi.org/10.1002/smr.1876)

[139] Miltiadis G. Siavvas, Kyriakos C. Chatzidimitriou, and Andreas L. Symeonidis. “QATCH - An adaptive framework for software product quality assessment”. In: Expert Systems with Applications 86 (2017), pp. 350–366. DOI: [10.1016/j.eswa.2017.05.060](https://doi.org/10.1016/j.eswa.2017.05.060)

[140] Manzoor Ahmad, Nicolas Belloir, and Brue. “Modeling and verification of Non-Functional Requirements of ambient Self-Adaptive Systems”. en. In: Journal of Systems and Software 107 (2015), pp. 50–70. DOI: [10.1016/j.jss.2015.05.028](https://doi.org/10.1016/j.jss.2015.05.028)

[141] D. Ameller et al. “Dealing with Non-Functional Requirements in Model-Driven Development: A Survey”. In: IEEE Transactions on Software Engineering (2019), pp. 1–1. DOI: [10.1109/TSE.2019.2904476](https://doi.org/10.1109/TSE.2019.2904476)

[142] Patrik Berander and Anneliese Andrews. “Requirements Prioritization”. In: Engineering and Managing Software Requirements. Ed. by Abyüke Aurum and Claes Wohlin. Berlin, Heidelberg: Springer, 2005, pp. 69–94. ISBN: 978-3-540-28244-0.

[143] J. D. Blaine and J. Cleland-Huang. “Software Quality Requirements: How to Balance Competing Priorities”. In: IEEE Software 25.2 (2008), pp. 22–24. DOI: [10.1109/MS.2008.46](https://doi.org/10.1109/MS.2008.46)

[144] C. Ebert. “Looking into the Future”. In: IEEE Software 32.6 (2015), pp. 92–97. DOI: [10.1109/MS.2015.142](https://doi.org/10.1109/MS.2015.142)

[145] Andrea Herrmann, Daniel Kerkow, and Joerg Doerr. “Exploring the Characteristics of NFR Methods – A Dialogue About Two Approaches”. en. In: Requirements Engineering: Foundation for Software Quality. Springer, Berlin, Heidelberg, 2007, pp. 320–334. DOI: [10.1007/978-3-540-73031-6_24](https://doi.org/10.1007/978-3-540-73031-6_24)

[146] Marjan Leber et al. “Value Analysis as an Integral Part of New Product Development”. In: 24th DAAM International Symposium on Intelligent Manufacturing and Automation, 2013 69 (2014), pp. 90–98. DOI: [10.1016/j.proeng.2014.02.207](https://doi.org/10.1016/j.proeng.2014.02.207)

[147] Hao-Tien Liu. “The extension of fuzzy QFD: From product planning to part deployment”. In: Expert Systems with Applications 36.8 (2009), pp. 11131–11144. DOI: [10.1016/j.eswa.2009.02.070](https://doi.org/10.1016/j.eswa.2009.02.070)

[148] I. Ozkaya et al. “Making Practical Use of Quality Attribute Information”. In: IEEE Software 25.2 (2008), pp. 25–33. DOI: [10.1109/MS.2008.39](https://doi.org/10.1109/MS.2008.39)

[149] W. N. Robinson. “Monitoring software requirements using instrumented code”. In: Proceedings of the 35th Annual Hawaii International Conference on System Sciences. 2002, pp. 3967–3976. DOI: [10.1109/HICSS.2002.994468](https://doi.org/10.1109/HICSS.2002.994468)

[150] Colette Rolland and Camille Salinesi. “Modeling Goals and Reasoning with Them”. In: Engineering and Managing Software Requirements. Ed. by Abyüke Aurum and Claes Wohlin. Berlin, Heidelberg: Springer Berlin Heidelberg, 2005, pp. 189–217. ISBN: 978-3-540-28244-0. URL: [https://doi.org/10.1007/3-540-28244-0_9](https://doi.org/10.1007/3-540-28244-0_9)

[151] A. Vickers. “Satisfying Business Problems”. In: IEEE Software 24.3 (2007), pp. 18–20. DOI: [10.1109/MS.2007.86](https://doi.org/10.1109/MS.2007.86)

[152] M. Vierhauser et al. “Developing a DSL-Based Approach for Event-Based Monitoring of Systems of Systems: Experiences and Lessons Learned (E)”. In: 2015 30th IEEE/ACM International Conference on Automated Software Engineering (ASE). 2015, pp. 715–725. DOI: [10.1109/ASE.2015.25](https://doi.org/10.1109/ASE.2015.25)

[153] S. Wagner et al. “Operationalised product quality models and assessment: The Quamoco approach”. en. In: Information and Software Technology 62 (2015), pp. 101–123. DOI: [10.1016/j.infsof.2015.02.009](https://doi.org/10.1016/j.infsof.2015.02.009)

[154] K. Allix et al. “AndroZoo: Collecting Millions of Android Apps for the Research Community”. In: 2016 IEEE/ACM 13th Working Conference on Mining Software Repositories (MSR). 2016, pp. 468–471. DOI: [10.1109/MSR.2016.056](https://doi.org/10.1109/MSR.2016.056)

[155] Jan Bosch and Petra Bosch-Sijtsema. “From integration to composition: On the impact of software product lines, global development and ecosystems”. In: St: Top Scholars 83.1 (2010), pp. 67–76. DOI: [10.1016/j.jss.2009.06.051](https://doi.org/10.1016/j.jss.2009.06.051)
Non-Functional Requirements in DevOps: A Systematic Mapping Study

[176] Nils Urbach et al. “The Impact of Digitalization on the IT Department”. en. In: Business & Information Systems Engineering 61.1 (2019), pp. 123–131. DOI: 10.1007/s12599-018-0570-0

[177] Philipp Haindl, Reinhold Plösch, and Christian Körner. “A Research Preview on TAICOS - Tailoring Stakeholder Interests to Task-Oriented Functional Requirements”. In: Requirements Engineering: Foundation for Software Quality. LNCS 11412. Essen, Germany: Springer Nature Switzerland, 2019, pp. 1–7. ISBN: 978-3-030-15537-7. DOI: 10.1007/978-3-030-15538-4_22

[178] Y. Yang et al. “Actionable Analytics for Software Engineering”. In: IEEE Software 35.1 (2018), pp. 51–53. DOI: 10.1109/MS.2017.4541039

[179] F. Fotrousi, S. A. Fricker, and M. Fiedler. “Quality requirements elicitation based on inquiry of quality-impact relationships”. In: 2014 IEEE 22nd International Requirements Engineering Conference (RE). 2014, pp. 303–312. DOI: 10.1109/RE.2014.6912272