

Variability in quality attributes of service-based software systems: A systematic literature review

Master thesis

Faculty of Mathematics and Natural Sciences
University of Groningen

Submitted by: Sara Mahdavi Hezavehi
Student number: s1951297

First supervisor: Paris Avgeriou
Second supervisor: Alexander Lazovik
Advisor: Matthias Galster



Abstract

Context and problem: Variability in software systems is generally understood as the ability of a software artifact to be changed for a specific context, in a preplanned manner. Even though variability is primarily studied in the software product line (SPL) domain, variability can occur in any software system. Moreover, variability not only affects functionality or features, but also quality attributes (QA). Considering QA throughout software development is crucial to ensure systems that meet quality requirements. It is complex to handle variability due to the growing number of constraints and also different possible configurations. However, how to handle variability in QA and in particular in service-based software systems has not received enough attention from researchers and still causes problems in software and service engineering practice.

Thesis objective: Before we thoroughly address the problem of variability in QA in service-based systems, an understanding of this topic is needed. Thus, the objective of this research is to systematically study variability of QA in service-based systems and to get an insight into the current status of research issues. In detail, the goals of the thesis are a) to assess methods for variability in quality attributes b) to collect evidence about current research that suggests implications for practice, and c) to identify research trends, open problems and areas for improvement.

Methods: We apply empirical research and conduct a systematic literature review (SLR). The research questions of our review are: RQ1: What methods to handle variability in quality attributes of service-based systems exist? RQ2: How much evidence is available to adopt proposed methods? RQ3: What are the limitations of current methods? The SLR includes an automatic search, rather than a manual search of software engineering venues.

Results: The results of our systematic review consists of a list of methods to handle variability in QA, including evidence for the validity of those methods (this list can be used by practitioners to select a specific method in a particular context). Moreover, based on these results we identify the current status of the research and open areas and propose guidelines for further research in this domain. In detail, our results suggest that design-time quality attributes are almost non-existent in current approaches available for practitioners, and product line engineering as the traditional discipline for variability management has almost no influence how we deal with variability in quality attributes of service-based systems. Furthermore, current approaches proposed by the research community do not provide enough evidence for practitioners to adopt these approaches. Also, variability has mainly been studied in laboratory settings, leaving many unsolved challenges for practitioners.

Acknowledgments

I would like to thank Qing Gu and Klaas-Jan Stol for their cooperation in reviewing my SLR protocol.

I would like to show my appreciation to Matthias Galster whose guidance and support from the initial to the end of my thesis enabled me to develop an understanding of the topic and successfully finish my research.

I am heartily thankful to my supervisor, Paris Avgeriou, for his encouragement, and support throughout my whole studies.

Lastly, my deepest gratitude goes to my parents, Vajie and Mohammad, my spouse Amirhossein, and my brother Sasha, for their unflagging love and support at every moment of my life.

Table of Contents

Abstract	1
List of Figures	5
List of Tables	6
List of Abbreviations	7
1. Introduction	9
1.1. Background	10
1.1.1. Service-based systems	10
1.1.2. Quality attributes in service-based systems	10
1.1.3. The notion of variability	11
1.2. Problem statement and motivation.....	12
1.2.1. Variability in quality attribute in service-based systems	12
1.2.2. Relevance and motivation	12
1.2.3. Lack of existing reviews.....	12
1.3. Thesis goals and contribution	14
1.4. Thesis structure.....	14
2. Research method: Systematic Literature Review	16
2.1. Overview of the systematic literature review method.....	16
2.2. Research questions	16
2.3. Search strategy.....	17
2.3.1. Search method	18
2.3.2. Search terms for automatic search.....	18
2.3.3. Scope of search and sources to be searched	19
2.3.4. “Quasi-gold” standard for automatic search	22
2.3.5. Inclusion and exclusion criteria.....	22
2.3.5.1. Inclusion criteria.....	22
2.3.5.2. Exclusion criteria	22
2.3.5.3. Applying inclusion and exclusion criteria.....	23
2.3.6. Search process	24
2.4. Quality criteria	26
2.5. Data extraction.....	26
2.6. Data aggregation, synthesis, and analysis	29

2.7.	Deviations from original protocol	30
3.	Results	31
3.1.	Results overview and demographics	31
3.2.	RQ1: What methods to handle variability in QA in service-based systems exist?	38
3.2.1.	RQ1.1: What types of variability do these methods handle?	38
3.2.1.1.	Runtime quality attributes	38
3.2.1.2.	Design time quality attributes.....	40
3.2.1.3.	Domains of methods	40
3.2.2.	RQ1.2: What activities in the development process are addressed by the methods?.....	42
3.2.3.	RQ1.3: What is the impact of the product line domain on handling variability in quality attributes of service-based systems?	45
3.3.	RQ2: How much evidence is available to adopt proposed methods?	47
3.4.	RQ3: What are the limitations of current methods?	53
3.4.1.	RQ3.1: Are methods only applicable to certain types of variability?	54
3.4.2.	RQ3.2: Are there no practitioner-based guidelines?	54
4.	Discussion of results.....	57
5.	Problems faced during the review, limitations and threats to validity	58
5.1.	Problems encountered during searching phase	58
5.2.	Limitations of the review and threats to validity.....	59
6.	Summary and conclusion	61
	References	62
	Appendix A- Detailed search strings	65
	Appendix B- Results of manual search for quasi-gold standard	78
	Appendix C – Data extraction table	78

List of Figures

Figure 1- Thesis structure.	15
Figure 2- Search process.	25
Figure 3- Publications per year.	32
Figure 4- Distribution of papers per venue categories.	37
Figure 5- QA sets and their appearance in papers.....	39
Figure 6- Number of addressed QAs per paper.	40
Figure 7- Development process activities sets and their appearance in papers.	44
Figure 8- Papers that address none, one, or multiple development activities.....	44
Figure 9- Solution approaches used by methods.....	46
Figure 10- Quality scores of papers.	49

List of Tables

Table 1-Searched electronic sources, and used search strings.	20
Table 2- Result of manual search used to form "quasi-gold" standard.	22
Table 3- Filtering steps based on inclusion/exclusion criteria.	23
Table 4- Data extraction form.	26
Table 5- Solution types.	27
Table 6- Development activities with an emphasis on architecture activities.	27
Table 7- Limitations of methods.	28
Table 8- Evaluation approaches.	29
Table 9- Assessed papers with titles, sources and addressed runtime QAs.	32
Table 10- Venue categories.	35
Table 11- Four main venue categories.	36
Table 12- Sub-categories of the software engineering category.	37
Table 13- Runtime QAs addressed by assessed studies.	38
Table 14- Possible sets of runtime QAs and the number of papers addressing these QAs sets.	38
Table 15-List of design time QAs addressed by papers.	40
Table 16-Reviewed studies belonging to single domain.	41
Table 17- Reviewed studies belonging to multiple domains.	41
Table 18- Development activities addressed in studies.	42
Table 19-Single and sets of development activities addressed in assessed studies.	43
Table 20- Nature of proposed solutions and papers.	45
Table 21- Solution type sets and papers using them.	45
Table 22- Citation counts and gained quality scores.	47
Table 23- Papers with citation counts.	48
Table 24- Papers assigned to each score per question.	50
Table 25- Papers assigned per answers of Q4.	51
Table 26- Papers assigned to evidence levels.	51
Table 27- Papers assigned to evaluation approaches.	52
Table 28-Paper limitations.	53
Table 29-Papers assigned to research/practice/ or both.	55
Table 30-Papers that provide tool support, and brief tool descriptions.	55

List of Abbreviations

Abbreviation	Explanation
A	Availability
AA	Architecture analysis
ADp	Architecture documentation and description
ADs	Architecture design
AE	Architecture evaluation
AI	Architecture implementation
AIA	Architecture impact analysis
AM	Architecture maintenance
AR	Express variability as part of a technique that models the architecture of the system
AR	Architecture recovery
AR	Availability and reliability
ARS	Availability and reliability and security
AS	Architecture synthesis
AS	Availability and security
C	Cost
CS	Case study
DC	Discussion
DS	Domain-specific language
EA	Example application
EP	Experience
FE	Field experiment
FM	Formal techniques based on mathematics
II	Implementation and integration
L	Learning curve
LH	Laboratory experiment with human subjects
LS	Laboratory experiment with software subjects
M	Maintenance
MF	Feature model
NL	Using natural language
O	Other limitations which should be named
ON	Ontology based techniques
OR	Orthogonal variability management
P	Performance
PA	Performance and availability
PAR	Performance and availability and reliability
PARS	Performance and availability and reliability and security
PR	Performance and reliability
PS	Performance and security
PSR	Performance and security and reliability

QA	Quality attribute
R	Requirements
R	Reliability
RA	Rigorous analysis
RS	Reliability and security
S	Security
SI	Simulation
SPL	Software product line
SV	Expressed variability as part of a technique that models services of the system
T	Testing
T	Time
UM	Using UML and its extensibility

1. Introduction

Service-oriented architectures (SOA) have become a widely used concept in software engineering research and practice. SOA¹ support highly adaptive systems in heterogeneous and frequently changing environments [3]. However, we currently lack software engineering methods that would truly support variability in service-based systems. Such methods would help design generic service-based systems that can be adapted in different organizations and for changing situations. Even the eight fundamental design principles of service-orientation do not consider variability as a key issue² when designing service-oriented systems [5].

Facilitating variability in software-intensive systems is essential to make sure that systems successfully adapt to changing needs, such as altering requirements. In service-based systems, variability is usually achieved through flexible service retrieval and binding, mostly focusing on functional aspects and neglecting quality attributes (QA). Moreover, methods to treat variability in service-based systems tend to focus on process workflow variability. Therefore, the objective of this thesis is to present a systematic literature review which describes the state-of-the-art of variability in quality attributes of service-based systems. We are particularly interested in a) assessing the quality of current research, b) collecting evidence about current research that suggests implications for practice, and c) identifying research trends, open problems and areas for improvement.

Even though variability is primarily studied in the software product line (SPL) domain (e.g., as service-oriented product lines), variability can occur in any service-based software system and is a concern of many, if not most, systems [6]. Moreover, variability not only affects functionality or features, but also quality attributes. Considering QA throughout software development is crucial to ensure systems that meet quality requirements (e.g., performance, safety). How to handle variability in QA of service-based systems has not received enough attention from researchers. In particular, understanding how variability in QA affects other QA or functionality, or how variability in features affects QA still causes problems in software engineering practice. However, before we could address these problems, we need to identify all current methods to handle variability in quality attributes of SOA. The proposed systematic literature review is thus concerned with *variability in quality attributes of service-based software systems*. Our review aims at identifying, evaluating and interpreting all available research relevant to variability in quality attributes of service-based systems.

¹ We use the terms “service-oriented architecture”, “service-oriented / -based software”, “service-oriented / -based applications” and “service-oriented / -based systems” interchangeable (each service-oriented / -based software or system has an underlying service-oriented architecture).

² On the other hand, a strategic goal of service-oriented computing is increased organizational agility. This means, new and changing business requirements should be fulfilled more rapidly by leveraging the reusability and interoperability of existing services.

1.1. Background

In the following section we briefly describe the definitions we use in this review. We clarify the meaning of service-based systems, notion of variability, and quality attributes in service-based systems.

1.1.1. Service-based systems

Service-orientation is a standard-based, technology-independent computing paradigm for distributed systems. As there is no universal definition for service, service-oriented architecture or service-oriented development [22], we utilize a broad definition: We consider service-oriented development as the development of a system which is assembled from individual services that are invoked using standardized communication models [3, 7]. The two important principles of an SOA are a) the identification of services aligned with business drivers, and b) the ability to address multiple execution environments by separating the service description (i.e., interface) from its implementation [46]. Moreover, literature distinguishes different types of service-oriented architectures [5]: 1) Service architectures (architectures of single services), and 2) service composition architectures (architectures for a set of services assembled into a service composition, i.e., a service-based system).

1.1.2. Quality attributes in service-based systems

For quality attributes, we adapt the definition proposed by the IEEE Standard Glossary for Software Engineering Terminology [9]. A quality attribute is a feature or characteristic that affects an item's quality. Here, quality describes to which degree a system meets specified requirements. Furthermore, we refer to quality attributes as discussed in the SWEBOK guide [16]. This guide integrates other quality frameworks, such as the IEEE Standard for a Software Quality Metrics Methodology [8, 17], or ISO standards [18-21]. The SWEBOK considers various attributes important for obtaining a software design of good quality – various “ilities” (maintainability, portability, testability, and traceability), various “nesses” (correctness, robustness). As with variability, a distinction is made between quality attributes “discernible” at runtime (performance, security, availability, functionality, usability), those not “discernible” at runtime (modifiability, portability, reusability, integrability, and testability), and those related to the architecture's intrinsic qualities (conceptual integrity, correctness, and completeness, buildability). Our work focuses on qualities “discernible” at runtime. As our results will show, design time QA are not a primary concern of current research.

Moreover, Gu and Lago found more than 50 quality-related challenges in service-based systems, including security, reusability, flexibility, interpretability, and performance [10]. These quality-related issues are emphasized due to the dynamic nature of service-oriented systems. Furthermore, O'Brien et al. discuss quality attributes in service-based systems and identified the most significant attributes in the context of SOA [22]. A quality model for service-based systems has also been proposed in the S-Cube project [23]. S-Cube reference quality model presents a full list and definitions of quality attributes in domain of service-based applications and also provides the justification why the quality attributes are included in the list. Based on these analyses we aggregate the following list of quality attributes that we consider in our study:

1. **Reliability:** Reliability is the ability of the system to remain operating over time. Two important aspects of reliability in SOA are the reliability of messages passing between the application and services, and also the reliability of services [22].
2. **Availability:** Availability is the degree to which a system or component is operational and accessible when it is needed. A SOA is considered to be successful if services are available to both, users and providers [22].
3. **Security:** Security is associated with a) confidentiality (access to information/service is granted only to authorized subjects), b) authenticity (we can trust that the indicated author/sender is the one responsible for the information, and c) integrity (information is not corrupted) [22].
4. **Performance:** Performance may have different meanings in different contexts, but it is mainly related to response time, throughput, or timeliness [22].

In this study we are only interested in the variability of aforementioned quality attributes with definitions presented above. However, if the queries that we use in our review (see section 2.3.2) return studies addressing other quality attributes, we will not exclude them from our results, and we will use them in our data analysis phase (see section 3.2.1.1).

1.1.3. The notion of variability

In the context of this work, variability is understood as the ability of a software artifact to be changed (e.g., configured, extended, adapted) for a specific context, in a preplanned manner [12]. It specifies parts of the system and its architecture which remain variable, or are not fully defined during design time. Variability allows the development of different versions of an architecture / system. Variability in the architecture is usually introduced through variation points, i.e., locations where change may occur. An architecture in which variability is introduced maybe be considered as some kind of “generic architecture”. On the other hand, there are architectures for which choices have been made and variants at variation points are implemented³.

Variability occurs in different phases of the software life cycle [13]. Design time variability defines variability at design time of the architecture. New architectures or systems are implemented using the generic architecture that includes variation points and applying variations to support variants. Creating a generic architecture often means finding the commonalities between similar architectures and applications and introducing variations where differences occur. Then, variations for the generic architecture can be designed so that they cover all variants identified in the requirements. Evolution of software architectures is another concern. Evolution would be a change to the generic architecture not through customization of the architecture but introduced by changes over time. However, evolution is usually considered separate from variability.

Based on Schmid and John [14], we define variability management as all activities related to explicitly representing variability in software artefacts throughout the lifecycle, managing dependencies among

³ Please note that we do not differentiate variability and flexibility. Some researchers argue that flexibility refers to the adaptation and change of an architecture, whereas variability deals with the different versions of an architecture.

different variabilities, and supporting the instantiations of those variabilities. This means, we interpret variability as planned change, rather than change due to errors, maintenance or new unanticipated customer needs, as investigated in [15].

1.2. Problem statement and motivation

In this section we describe our motivations for doing this research, and problems which made us to undertake this review.

1.2.1. Variability in quality attribute in service-based systems

Variability in quality attributes of service-based systems refers to two aspects: First, a service can be delivered with several levels of QA to fulfill the expectation of different groups of service consumers. Second, it means that the architecture is capable of dealing with different levels of QA (e.g., performance) and at the same time ensures other QA (e.g., reliability). Although SOA provides some degree of variability, still we lack in software engineering methods to handle the variability of QAs in service-based systems. Therefore, to address this problem, we need to first find out what current methods are, how they work, and what benefits and disadvantages they have.

1.2.2. Relevance and motivation

Although several reviews and studies have been presented in similar fields of study such as variability management in the product line domain [25], service-based systems [26], variability-intensive SOA systems [27], and service-oriented system engineering [10], we could not identify any existing systematic reviews or comprehensive studies on variability in service-oriented systems that focus on quality aspects. This motivated us to conduct a literature review in order to summarize all existing information about variability of quality attributes in service-oriented systems (see also section 1.2.3).

In detail, there are three reasons why we perform a systematic review: First, we want to summarize existing evidence related to variability of quality attributes in service-oriented systems. Second, we want to identify gaps in current research. This will help us suggest areas for further investigation towards solving the variability problem in SOA. Third, the review will help us position our new research activities. We need to identify the existing base for our research and make clear where the proposed research fits into the current body of knowledge (in the software engineering domain, this body of knowledge is documented in the SWEBOK).

1.2.3. Lack of existing reviews

As mentioned before, the need for a review arises from the necessity to summarize all existing information about variability of quality attributes in service-oriented systems. We could not identify any systematic reviews or studies which particularly consider variability in service-oriented systems focusing on quality aspects. However, a review that comes close to our review was presented by Chen et al. and reviewed 33 approaches for variability management in the product line domain [25]. The objectives of this study were a) to identify approaches for variability management in the product line domain, b) to determine if the research on variability management approaches has evolved, and c) to identify the key issues that have been driving the evolution of variability management approaches. The study found that most current work addresses variability in terms of features, assets or decisions. Also, most work has

been done on variability modeling; only little work has been presented to resolve variability at any time of the software life-cycle (including runtime). Even though certain search terms, data sources, as well as inclusion and exclusion criteria in this study might overlap with ours, there are three main differences between Chen et al. and our study: First, we focus on quality aspects rather than on variability of features. Second, we focus on the domain of service-oriented systems. Third, our research questions differ. Moreover, we believe that variability in service-oriented systems differs from variability in product lines and thus makes Chen et al. systematic literature review not applicable to our problem:

- a. Variability in service-based systems occurs at different levels of abstraction. For example, variability might be provided through parameter values used to invoke a service, or by replacing complete services. Product lines on the other hand usually address flexibility explicitly, in terms of features, assets or decisions, i.e., on a higher conceptual level.
- b. Variability in service-oriented systems needs to consider the integration of services, third party applications, organization-specific systems and legacy systems. Service-oriented systems present a dual challenge of meeting requirements for each organization while crossing boundaries between organizations [28]. Such systems run in the context of a volatile, distributed service composition environment in which services can change, fail, become temporarily unavailable, or disappear.
- c. Dynamic runtime variability and re-binding and re-composition at runtime must be supported. Product lines focus on compile time variability [29]. However, to fully support variability in service-oriented systems, events that occur in such systems must be coupled with the use of rules to reason about execution alternatives [30].
- d. Service-oriented computing includes its own design paradigm and design principles, design patterns, a distinct architectural model, and related concepts, technologies, and frameworks [5].

A broad review on service-based systems was carried out by Brereton et al. [26]. This review aimed at a) identifying main issues that need to be addressed to successfully implement service-based systems, b) identifying solutions that have been proposed to address issues raised, c) identifying research methods used to investigate proposed solutions, d) providing frameworks for positioning new research activities, and e) identifying gaps in new research. The review concluded that main issues that need to be addressed are change, selection and co-ordination. Solutions presented mainly focus on technologies. Research methods primarily used are those of concept implementation and conceptual analysis. Moreover, a framework was proposed and the gaps identified included topics relating to business and people-oriented issues. Even though the goals and the topic area are quite similar to ours, we perform a more specific search by focusing on variability and quality. Also, our method is different: We search more than only six journals (as done by Brereton et al.), and apply quality criteria to selected studies. We also perform a more formal data analysis. Most importantly however, Brereton et al. study focused on the period from 2000 to 2004. However, many publication venues (in particular conferences and workshops for SOA researchers) were established during the last five years.

Kontogogos and Avgeriou studied variability-intensive SOA systems [27]. Their review differentiates integrated variability modeling (extending traditional software artifacts with variability) and orthogonal variability modeling (adding new representations of variability separately from existing software). They found that most current approaches that could be applied to variability modeling in SOA are feature-based and stem from the product line domain. However, their study does not focus on quality aspects of SOA. Moreover, based on Kitchenham et al., their study cannot be considered as a systematic literature review but as an informal literature survey [6]. It does not provide research questions, no search process as well as no data extraction process. The goal of the review was to gain insight into the current status of research issues.

In 2009, Gu and Lago presented a systematic literature review on service-oriented system engineering [10]. The goal of the review was to gain insight into the current status of research issues. The study explored challenges that have been claimed between January 2000 and July 2008. In this review, of the 729 publications that have been examined, 51 were selected as primary studies, from which more than 400 challenges were elicited. The study concluded that challenges can be classified along two dimensions: a) based on themes (or topics) that they cover, and b) based on characteristics (or types) that they reveal. By analyzing the distribution of the challenges on the topics and types in the years 2000–2008, the paper pointed out a trend in service research activities, with quality as the top challenge.

1.3. Thesis goals and contribution

Before we can thoroughly address the problem of variability in QA, an understanding of this topic is needed. Thus, the objective of this research is to systematically study variability of QA in service-intensive systems and to get an insight into the current status of research issues. In detail, the goals of the thesis are a) to identify methods used to handle variability of quality attributes, and b) to identify areas for improvements.

The results of the research consist of a) a list of methods to handle variability in QA, including evidence for the validity of those methods (this list can be used by practitioners to select a specific method in a particular context), and b) a list of limitations and deficiencies of current variability methods.

1.4. Thesis structure

This thesis is organized in six chapters. Chapter one consists of a) a background about service-based systems and quality attributes in service-based systems, and notion of variability in the context of our work, b) the problem statement which describes variability in quality attributes of service-based systems, including its relevance and motivation, and c) a discussion of thesis goals and contributions. Chapter two gives an overview of the systematic literature review method. We introduce our research questions, discuss our search strategy and method, quality criteria, data extraction, aggregation, synthesis and analysis. In chapter two we also discuss deviations from the original review protocol. Chapter three presents the results. Here, we first give an overview of the results and provide various demographic information about the studies included in the review. Then, data analysis is provided to answer each research question. Chapter four presents main points and findings of this review based on the analysis done in chapter three. Chapter five discusses the problems and limitations we encountered

during our research and how we handled them. Finally, chapter six includes a conclusion and summary of the thesis and presents suggestions for future work. Figure 1 shows an overview of thesis structure and the relations between different parts of the thesis.

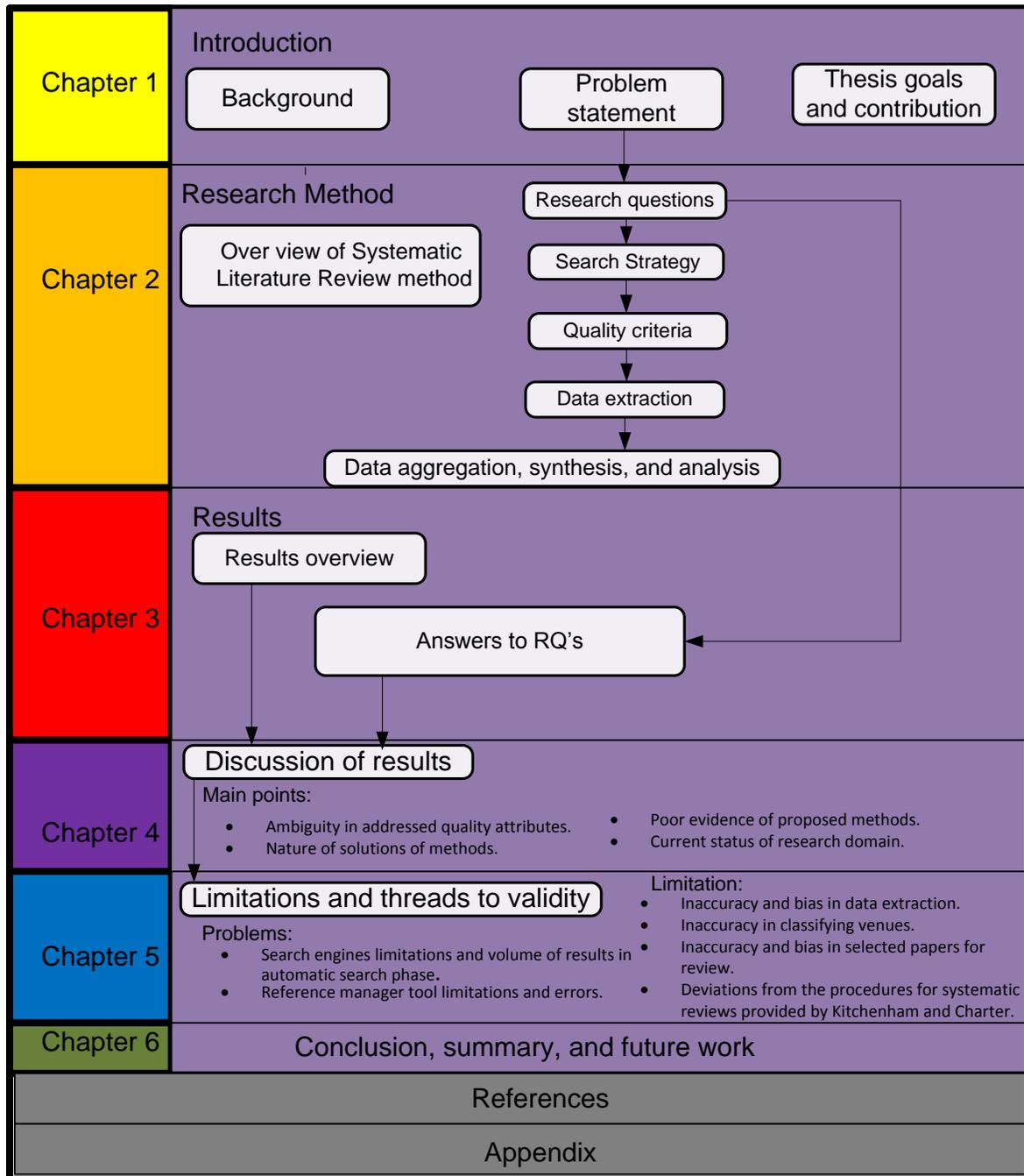


Figure 1- Thesis structure.

2. Research method: Systematic Literature Review

This chapter describes our research method for SLR in detail.

2.1. Overview of the systematic literature review method

We conduct a systematic literature review, which is a well-defined method to identify, evaluate and interpret all relevant studies regarding a particular research question, topic area or phenomenon of interest [43]. A systematic literature review gives a fair, credible and unbiased evaluation of a research topic using a trustworthy, rigorous and auditable method. A common reason for undertaking a systematic review is to summarize existing studies concerning a technology. Thus, a systematic literature review is an appropriate method for our research that aims at identifying and evaluating variability in quality attributes of service-based systems.

The methodology used in this research is based on Kitchenham's procedures for performing systematic literature reviews [43]. Furthermore, we draw on practical experience with systematic literature reviews (e.g., Staples and Niazi [47], Biolchini et al. [48] or Riaz et al. [49]) as well as on meta-studies (e.g., Zhang and Babar [24] or Kitchenham et al. [50-51]).

A significant step when performing a systematic literature review is the development of a review protocol. The protocol impacts how the review is conducted and specifies all steps performed during the review. This protocol reduces researcher bias and increases the rigor and repeatability of the review. The protocol specifies the review plan and procedures by describing the details of various strategies for performing the systematic review. In particular, it defines the research questions, search strategy to identify the relevant literature, inclusion and exclusion criteria for selecting relevant studies, and the methodology for extracting and synthesizing information in order to address the research questions.

When designing the protocol, we first identified the search scope and decided on a search strategy. We designed the search string to be used to search on various electronic sources. As part of this step, we performed a number of pilot searches to test the search terms. Defining a good search string was important to get a high recall rate, with a high precision rate. Then, we developed a number of study selection criteria, in particular inclusion and exclusion criteria for studies that were identified in the search phase. Also, we proposed our strategy for assessing the quality of studies that we considered in the review. Next, we decided on the data elements to be extracted from the selected studies to help answer the research questions. As the final step of our protocol, we presented our strategy to synthesizing the extracted data and how to present the results of this synthesis.

The protocol was reviewed by external reviewers and changes were made accordingly.

2.2. Research questions

In order to achieve the goal of our study which we mentioned before, we aim at answering several research questions. Therefore, proposing the appropriate questions is a critical task in our work. Research questions must be meaningful and important not only to researchers, but also to practitioners. Moreover, the questions should help identify and scope future research. Therefore, we define the goal

of the study through Goal-Question-Metric (GQM) perspectives [11]. Based on the goal, we then derive specific research questions. The goal in terms of GQM is as follows:

Purpose: analyze and characterize

Issue: variability in quality attributes

Object: in service-oriented systems

Viewpoint: from a researcher's and practitioner's point of view

Thus, our general research question is "How is variability in quality attributes managed in service-based systems?". In detail, our study covers the following primary research questions:

RQ1: What methods to handle variability in QA in service-based systems exist?

RQ1.1: What types of variability do these methods handle?

RQ1.2: What activities in the development process are addressed by the methods?

RQ1.3: What is the impact of the product line domain on handling variability in QA in service-based systems?

RQ2: How much evidence is available to adopt proposed methods?

RQ3: What are the limitations of current methods?

RQ3.1: Are methods only applicable to certain types of variability?

RQ3.2: Are there no practitioner-based guidelines?

We pose RQ 1 to get an overview of existing methods, and to investigate which quality attributes are currently addressed most and which ones are rarely addressed. We pose RQ2 to help practitioners decide what methods they might use. Furthermore, RQ2 helps researchers assess the quality of existing research. RQ3 helps us outline directions for future research and identifies areas that need work in order to make methods more applicable in practice.

Even though some of our questions are high level, we perform a systematic literature review rather than a mapping study (or scoping review) as we want to aggregate the outcomes of primary studies, rather than only classify literature.

2.3. Search strategy

The strategy is important so that relevant studies can be expected to be included in the search results (high recall), without being cluttered by irrelevant search results (high precision). The search strategy is based on

- a. Preliminary searches to identify existing systematic reviews and assessing potential relevant studies,
- b. Trial searches and piloting using various combinations of search terms derived from the research questions,
- c. Reviews of research results, and

d. Consultation with experts in the field.

We decided to manually search a small number of venues in order to be able to cross check the result we obtained from automatic search, to create valid search strings, and possibly modify search strings. This is similar to determining a “quasi-gold” standard as proposed by Zhang and Babar [24]. Venues for the limited manual search are determined based on their significance for publishing research in the context of service-oriented computing. We also limited the manual search to a time interval shorter than the interval used for the automatic search. Thus, we manually searched the following venues over the period of January first of 2005 and 20th of February of 2011 (please note that these venues do not include workshops, such as SOSE and SDSOA, but only major conferences and journals):

- IEEE Transactions on Services Computing
- Journal of Service Oriented Computing and Applications
- International Conference on Service Oriented Computing
- International Conference on Services Computing
- International Conference on Web Services
- ServiceWave (2008, 2009, 2010)

When manually searching the venues, we considered title, keywords, and (if necessary) abstract. Then we compared the result with the result of automatic search using the search strings (see section 2.3.1) to have an estimation if we are missing any papers by applying automatic search. The results from the automatic search should include all studies found for the “quasi-gold” standard (i.e., the “quasi-gold” standard should be a subset of the results returned by the automatic search).

2.3.1. Search method

We used automatic search. By automatic search we mean search performed by executing search strings on search engines of electronic data sources. Manual search is not feasible for databases where the number of published papers can be over several thousand [44]. Moreover, manually searching journals and conferences might not cover all relevant venues (e.g., venues from other domains, such as the business domain). Searching databases helped us find studies in journals and conferences in which relevant research has been published. We included any type of study (empirical, theoretical, etc.) as there seemed to be no standard study approach in our problem domain.

2.3.2. Search terms for automatic search

We used our research questions and derived several search terms. We used a seven step strategy to obtain our search terms; our strategy was as follows:

1. Derive major terms from the research questions and the topics being researched.
2. Identify and include alternative spellings, plurals, related terms and synonyms for major terms.
3. Check keywords in any relevant paper that we already have and initial searches on the relevant databases.
4. When database allows, use Boolean “or” to incorporate alternative spellings and synonyms.

5. When database allows, use Boolean “and” to link the major terms from population, intervention and outcome.
6. Discussions between researchers.
7. Pilot different combinations of search terms in test executions and reviews.
8. Check pilot results with “quasi-gold” standard

Since we were particularly interested in Performance, Security, Reliability and Availability quality attributes in service-based systems, we included these quality attributes in our search terms. The search string consists of three parts: Service-orientation AND variability AND quality attributes. The alternate keywords are connected through logical OR to form a reference search string for automatic search of databases.

(service **OR** services **OR** service-oriented **OR** service oriented **OR** service-based **OR** service based **OR** SOA **OR** software as service **OR** software as a service **OR** SaS **OR** SaaS)

AND

(change **OR** changes **OR** modification **OR** modifications **OR** modify **OR** adaptive **OR** adapt **OR** adaptation **OR** aware **OR** flexibility **OR** flexibilities **OR** product line **OR** product lines **OR** product family **OR** product families **OR** variability **OR** variabilities **OR** variant **OR** variants **OR** variation **OR** variations **OR** variation point **OR** variation points)

AND

(aspect **OR** aspects **OR** cross-cutting **OR** non-functional **OR** quality **OR** qualities **OR** quality attribute **OR** quality attributes **OR** quality factor **OR** quality factors **OR** System Quality **OR** System Qualities **OR** QoS **OR** Quality of Service **OR** Service level **OR** Service-level **OR** SLA **OR** Performance **OR** Security **OR** Reliability **OR** Availability)

Our reference search string went through lots of modifications based on search features of electronic sources (e.g., different field codes, case sensitivity, syntax of search strings, and inclusion and exclusion criteria like language and domain of the study) provided by each of the electronic sources. This issue led us to use different search strings for different sources [43]. However, for each source we documented search strings (see appendix A). For each source, a semantically and logically equivalent search string was created.

2.3.3. Scope of search and sources to be searched

Our surveyed resources include electronic sources. The scope of our search is defined in two dimensions: publication period (time) and source. In terms of publication period, we limited our search to papers published over the period first of January of 2000 and 20th of February of 2011. This is because the first papers on service-oriented systems started to appear around ten years ago [10]. Furthermore, SOAP was first submitted to W3C in 2000 (SOAP allows the implementation of web services). Please note that even though major conferences on service-oriented computing started to emerge in 2004 (e.g., ICSOC), we chose to start the search in the year 2000 to avoid missing studies that

were not published at a service-specific venue. Moreover, the events on variability started to emerge in the year 2000 with the first product line conference.

For each data source, we documented the number of papers that was returned. Also, we recorded the number of papers left for each venue after primary study selection on the basis of title and abstract. Moreover, the number of papers finally selected from each source was recorded. The venues to be searched are shown in the table 1. The two right columns of table 1 are as follows: “Papers returned” indicates the number of papers which were found by the search engine by using the related search string, and the “Papers remained after filtering” indicates the number of papers which were downloaded to reference tool manager after performing a filtering based on the titles (and sometimes abstracts).

Table 1-Searched electronic sources, and used search strings.

Name of electronic data source	Search string	Papers returned	Papers remained after filtering
ACM Digital Library	(("service" or "services" or "SOA" or "SaS" or "SaaS") and ("change" or "modification" or "modify" or "flexibility" or "flexibilities" or "product line" or "product family" or "product families" or "variability" or "variabilities" or "variant" or "variation" or "variations" or "adaptive" or "adapt" or "aware") and ("aspect" or "cross-cutting" or "non-functional" or "quality" or "qualities" or "quality attributes" or "quality factor" or "Performance" or "Security" or "Reliability" or "Availability" or "QoS"))	3052	24
IEEE Xplore	"service" or "services" or "SOA" or "SaS" or "SaaS" and "change" or "modification" or "modify" or "flexibility" or "flexibilities" or "product line" or "product family" or "product families" or "variability" or "variabilities" or "variant" or "variation" or "variations" or "adaptive" or "adapt" or "aware" and "aspect" or "cross-cutting" or "non-functional" or "quality" or "qualities" or "quality attributes" or "quality factor" or "Performance" or "Security" or "Reliability" or "Availability" or "QoS"	2554	106
SpringerLink	((service or SOA) and (quality or qualities orQoS) and (va riability or adapt or change))	952	50
Web of Science	=((service OR service-oriented OR service oriented OR service-based OR service based OR SOA OR SaS OR SaaS)) AND Title=((change OR modification OR modifications OR modify OR flexibility OR flexibilities OR product line OR product lines OR product family OR product families OR variability OR variabilities OR variant OR variants OR variation OR variations OR variation point OR variation points OR adaptive OR adapt OR adaptation OR aware)) AND Title=((aspect OR cross-cutting OR non-functional OR quality OR qualities OR quality attribute OR quality factor OR System Qualities OR Performance OR Security OR Reliability OR Availability	65	25

	OR QoS OR Quality of Service OR Service level))		
Scopus	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level"	8904	8904
ScienceDirect	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" OR "Service-level" OR "SLA"	2237	2237

Note that search strings provided in this table only contain the search terms, and not all the inclusion/exclusion criteria used for actual search of electronic databases. Depending on the electronic databases search engine features, different filtering criteria were added to the string (see appendix A).

The quality of search engines influenced the completeness of our identified primary studies. This means, we might have missed those studies whose authors used other terms to specify variability or did not use the keywords that we used for the searches in title, abstract or keywords of the papers.

It is beyond the scope of this systematic review to search for and review work in form of PhD theses.

Thus, we excluded PhD theses from our review. We also excluded books from our review.

2.3.4. “Quasi-gold” standard for automatic search

Before applying inclusion and exclusion criteria on the automatic search results, we had to check if our search strings were appropriate, and we were not missing any papers in our automatic search results. So, we had to make sure that the results of the partial manual search, which were used to establish the “quasi-gold” standard, were a subset of automatic search results, and if not we had to refine our search strings. By manual search of the selected venues, which are listed in section 2.3, we got a result including 18 papers (to see the full list of number of papers per year and venues see appendix B). However, after going through several iterations and removing irrelevant papers we found out only 3 of them were related papers and those 3 relevant papers were also subset of the automatic search results. Table 2 presents the results we got from manual search of our selected venues to form the “quasi-gold” standard.

Table 2- Result of manual search used to form "quasi-gold" standard.

Authors	Title	Venues
Narendra, Nanjangud C. - Ponnalagu, Karthikeyan	Towards a Variability Model for SOA-Based Solutions	IEEE International Conference on Services Computing (2010)
Narendra, N.C. - Ponnalagu, Karthikeyan - Gomadam, Karthik - Sheth, Amit P.	Variation Oriented Service Composition and Adaptation (VOSCA): A Work in Progress	IEEE International Conference on Services Computing (2007)
Zhang, Liang-Jie - Arsanjani, Ali - Allam, Abdul - Lu, Dingding - Chee, Yi-Min	Variation-Oriented Analysis for SOA Solution Design	IEEE International Conference on Services Computing (2007)

2.3.5. Inclusion and exclusion criteria

In this section we describe the inclusion and exclusion criteria which helps to filter irrelevant papers, and get the most appropriate and relevant studies for our research.

2.3.5.1. Inclusion criteria

A paper needs to cover all of the following the inclusion criteria to be accepted for review:

1. Study is internal to service domain. We are interested in variability of quality attributes in service-based systems. This implies that studies are about service-based systems.
2. Study describes a method to handle variability in quality attributes. A study may provide evidence to adopt the proposed method, and discusses limitations of the method.
3. Study introduces an approach dealing with some aspect of quality variability in service-based applications.

2.3.5.2. Exclusion criteria

Moreover, papers should not have an intersection with items presented in the exclusion criteria. If a paper does have an intersection with any of the following items, then it should be excluded:

1. Study is external to service domain. Since we use “service” and related terms as keywords in the search strings, studies that are about service-based systems but are completely irrelevant to service-oriented systems should be excluded.
2. Study is marginally related to service-based systems. If the focus of a paper is about a field other than service-based systems and is only marginally related to service-oriented systems, the paper should be excluded. For example, a study that is mainly about how to design and develop health care information systems (based on SOA) should be excluded.
3. Study is in the domain of variability, but does not consider quality attributes. A paper that does not address variability has no value to our research questions.
4. Study is editorial, position paper, abstract, keynote, opinion, tutorial summary, panel discussion, or technical report. A paper that is not a scientific paper might not be of good quality and does not provide reasonable amount of information.
5. Study does have the same terminology for quality attributes, but definitions are different from what we explained before.

Inclusion and exclusion criteria are evaluated in the following way: Each study that is included in the search reviewed by one of the researches, who read title, keywords, and abstract to determine a paper’s relevance according to each criterion. When necessary, the content of the paper was also examined. For each reviewer result, another researcher independently performed sanity checks. Differences were reconciled collaboratively.

2.3.5.3. Applying inclusion and exclusion criteria

The filtering of automatic search results based on inclusion/exclusion criteria was performed in three steps. In the first step, we filtered papers based on the journals in which they were published and terms which were used in their titles. Irrelevant journals (such as journals from construction engineering) and papers including irrelevant terms such as bandwidth, IEEE, filter, WLAN, sensor, wireless, IP, CPU, TCP in their titles were excluded from our study. In fact we used these terms for a keyword search on the total results to get the possible irrelevant papers. Then we checked the results of the keyword search again to see if the papers are really irrelevant.

In the second step we filtered our results by removing papers having clearly irrelevant titles. We performed this step in two iterations.

Finally, in the third step we filtered the papers based on their abstracts and keywords. This step was performed in three iterations. Table below indicates these filtering stages and the number of papers at the beginning and before filtering. The initial number of papers at the first step is in fact the sum of the numbers in the right column of table3.

Table 3- Filtering steps based on inclusion/exclusion criteria.

Filtering Step	Initial number of papers at the step
Filtering of automatic search results based on journals and terms in titles	11346
Filtering of automatic search results based on titles	7230

(in two iterations)	
Filtering of automatic search results based on abstracts and keywords (in three iterations)	1993

In the second iteration of the last step we got 460 papers. Then we went through one last iteration and meticulously read all the abstracts once more and filtered 410 papers. So at the end, a set of filtered relevant papers including 50 papers remained for review. To ensure reliability of inclusion, two researchers checked the papers and disagreements were resolved.

2.3.6. Search process

We used a staged study selection process (figure-2) for our review. In stage 1 we searched databases listed in section 2.3.3. The search string searched in title, abstract and keywords. Initially, selection criteria were interpreted liberally, so that studies identified by the electronic search could be excluded based on titles and abstracts and conclusions. Brereton et al. argue that abstracts might be too poor to rely on when selecting primary studies [31]. Thus we also decided based on the conclusions of studies. Then, full copies of studies were obtained for the remaining studies. Final inclusion / exclusion decisions were made after full texts have been retrieved. For excluded studies, we documented a list of reasons for exclusion. In case of multiple studies referring to the same method, only the most recent was included.

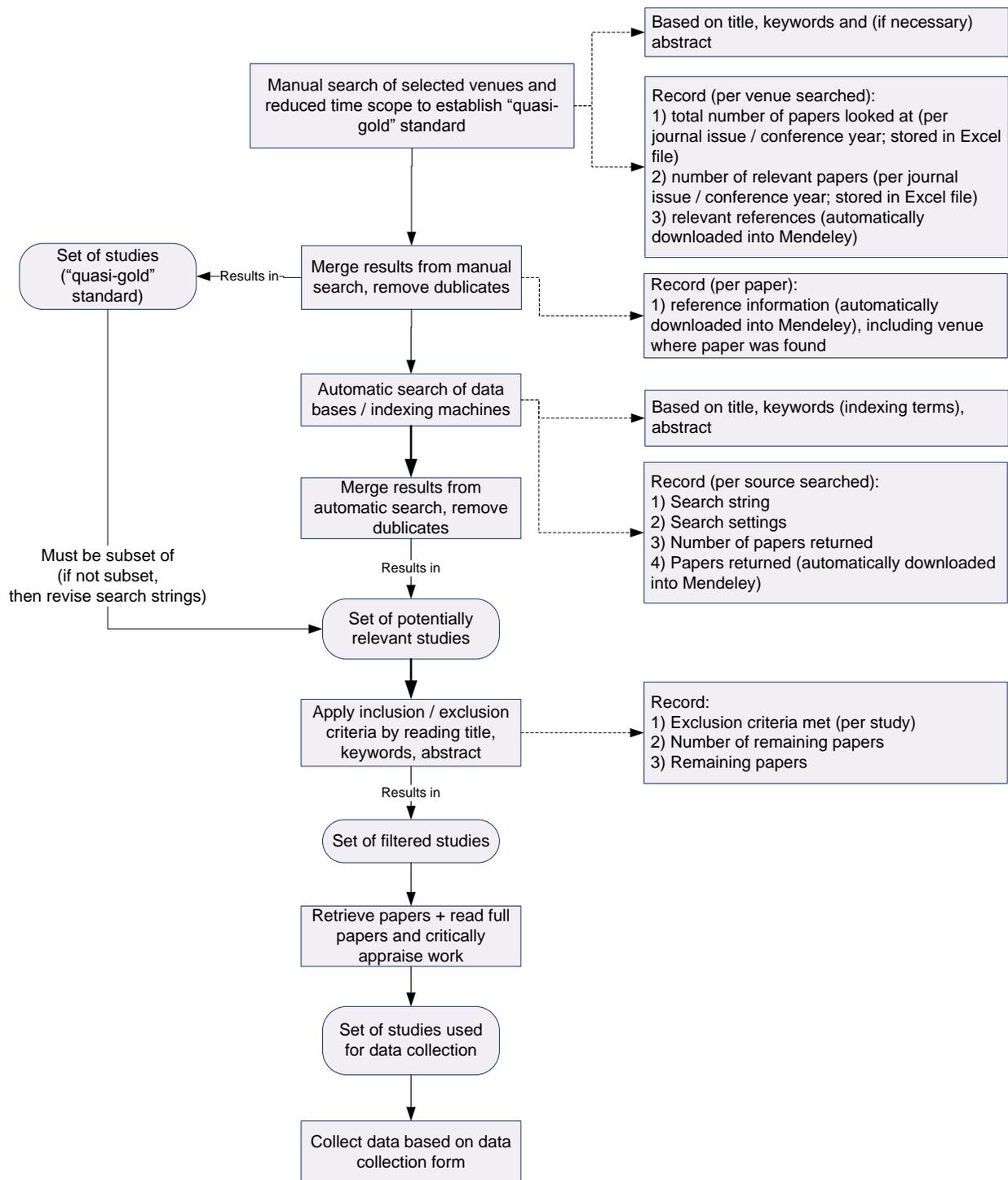


Figure 2- Search process.

2.4. Quality criteria

Instead of following the study design hierarchy for software engineering proposed in [43], we used quality criteria and all selected studies were assessed through a quality check. This was important for data synthesis and interpretation of results in further stage. All selected papers which were included in the review underwent this check. Thus, each study was evaluated against a set of questions with regard to the used method and the quality of the reporting. Similar as Ali et al. [33], we adopted the quality assessment instrument used by Dyba and Dingsoyr [34]. This instrument uses a three point scale to answer each question, either as “yes”, “to some extent” or “no”. By including “to some extent” we did not neglect statements where authors provided only limited information to answer the assessment questions. Each quality assessment question was answered by assigning a numerical value (1 = “yes”, 0 = “no”, and 0.5 = “to some extent”). Then, a quality assessment score was given to a study by summing up the scores for all the questions for a study (quality assessment score of a study). Quality criteria are:

- **Q1:** Is there a rationale for why the study was undertaken?
- **Q2:** Is there an adequate description of the context (e.g., industry, laboratory setting, products used, etc.) in which the research was carried out?
- **Q3:** Is there a justification and description for the research design?
- **Q4:** Does the study provide description and justification of the data analysis approaches?
- **Q5:** Is there a clear statement of findings and has sufficient data been presented to support them?
- **Q6:** Did the researcher critically examine their own role, potential bias and influence during the formulation of research questions and evaluation?
- **Q7:** Do the authors discuss the credibility and limitations of their findings explicitly?

2.5. Data extraction

The data extraction strategy defines how the information required from each primary study is obtained. The selected primary studies have been read in detail to extract the data needed in order to answer the research questions. Data was extracted using a data extraction form (table 4). The data extraction form is as follows:

Table 4- Data extraction form.

#	Field	Concern / research question
F1	Author(s)	Documentation
F2	Year	Documentation
F3	Title	Documentation
F4	Source	Reliability of review
F5	Keywords	Documentation
F6	Abstract	Documentation
F7	Citation count (Google scholar)	RQ2
F8	Quality score	RQ2
F9	Method proposed	RQ1
F10	Nature of solution	RQ1.3
F11	Domain	RQ1.1, RQ1.3, RQ3.1

F12	Runtime QA	RQ1.1, RQ3.1
F13	Design time QA	RQ1.1, RQ3.1
F14	Tool support	RQ3.2
F15	Development activities addressed	RQ1.2
F16	Limitations	RQ3
F17	Research / practice / both	RQ3.2
F18	Evidence level	RQ2
F19	Evaluation approach	RQ2

A record of extracted information was kept in a Mendeley file and spreadsheet for subsequent analysis. Some data on the extraction form are defined as numerical values (e.g., the quality score). This is important to summarize the results of a set of primary studies and for meta-analysis. Some data fields are explained below:

- **F8 (quality score):** The quality score is obtained using the schema introduced in section 2.4.
- **F9 (method proposed):** The proposed method is briefly described.
- **F10 (nature of solution):** Adapting types of solutions from [35], we utilize the following types indicated in table 5 :

Table 5- Solution types.

Abbreviation	Type of solution
MF	Feature model
UM	Using UML and its extensibility
AR	Express variability as part of a technique that models the architecture of the system
NL	Using natural language
SV	Expressed variability as part of a technique that models services of the system
FM	Formal techniques based on mathematics
DS	Domain-specific language
ON	Ontology based techniques
OR	Orthogonal variability management
Other	Other used solutions.

In addition to the solution types presented in the table above, other types of solutions can be applied.

- **F11 (Domain):** Application domain of approach.
- **F15 (Development activities addressed):** Adapting architecture activities from [45], we use the following activities indicated in table 6:

Table 6- Development activities with an emphasis on architecture activities.

Abbreviation	Activity
AA	Architecture analysis
AS	Architecture synthesis

AE	Architecture evaluation
AM	Architecture maintenance
AI	Architecture implementation
ADs	Architecture design
AR	Architecture recovery
ADp	Architecture documentation and description
AIA	Architecture impact analysis
II	Implementation and Integration
R	Requirements
T	Testing
M	Maintenance

It is also possible that **none** of the mentioned development activities is explicitly addressed in certain studies. This means that based on the data extracted from the papers it was not clear if any activity was addressed or not.

- **F16 (limitations):** Limitations include (see table 7):

Table 7- Limitations of methods.

Abbreviation	Limitation
T	Time
C	Cost
L	Learning curve
O	Other limitations which should be name.

- **F18 (evidence level):** Evidence level evaluates the evidence level of the proposed method. The results are critical for researchers to identify new topics for empirical studies, and for practitioners to assess the maturity of a particular method or tool. Kitchenham proposed five levels of study design in software engineering [43]. We revise this classification to make the assessment more practical, as proposed by Alves et al. [36]. From weakest to strongest, our classification is as follows:

- 1 - No evidence.
- 2 - Evidence obtained from demonstration or working out toy examples.
- 3 - Evidence obtained from expert opinions or observations.
- 4 - Evidence obtained from academic studies (e.g., controlled lab experiments).
- 5 - Evidence obtained from industrial studies (e.g., causal case studies)
- 6 - Evidence obtained from industrial evidence.

According to Alves et al., industrial practice indicates that a method has already been approved and adopted by industrial organizations [36]. Thus, practice shows a convincing proof that something works and is therefore ranked strongest in the hierarchy.

- **F19 (evaluation approach):** Based on [40], we use the following categorization for evaluation approaches (see table 8):

Table 8- Evaluation approaches.

Abbreviation	Evaluation approaches
RA	Rigorous analysis: Rigorous derivation and proof, suited for formal model [37].
CS	Case study: An empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used [38].
DC	Discussion: Provided some qualitative, textual, opinion-oriented evaluation. E.g. compare and contrast, oral discussion of advantages and disadvantages [39].
EA	Example application: Authors describing an application and provide an example to assist in the description, but the example is "used to validate" or "evaluate" as far as the authors suggest [37].
EP	Experience: The result has been used on real examples, but not in the form of case studies or controlled experiments, the evidence of its use is collected informally or formally [37].
FE	Field experiment: Controlled experiment performed in industry settings [40].
LH	Laboratory experiment with human subjects: Identification of precise relationships between variables in a designed controlled environment using human subjects and quantitative techniques.
LS	Laboratory experiment with software subjects: A laboratory experiment to compare the performance of newly proposed system with other existing systems [41].
SI	Simulation: Execution of a system with artificial data, using a model of the real world [42].

2.6.Data aggregation, synthesis, and analysis

Data from primary studies were collated and summarized. The extracted data is synthesized to answer the research questions. The synthesis includes the following:

1. Listing of findings of each paper according to research question
2. Categorizing findings and notes how many papers agree with each finding
3. Separation of findings identified in 2. to see whether there are any differences in the identified groups.

Since most of the selected studies are expected to be grounded in qualitative research, a meta-analytical approach might not be suitable for synthesizing the data. We used descriptive statistics (sum, average, frequency analyses, etc.) for analyzing the data. Moreover, we performed descriptive synthesis to represent the results in tabular form. Qualitative analysis was applied to data collected through field F9, F11 and F16.

2.7. Deviations from original protocol

- **Modification of search strings based on search engine capabilities and features.** Although at in our protocol we constructed a single search string for automatic search of databases, we needed to modify the strings based on the search engines capabilities and features. For instance, SpringerLink's search engine does not accept long search strings, so we had to change our search string remarkably and present it in a condensed format. To see the list of different strings we used in automatic search phase see table 1 (and also appendix A).
- **List of software architecture activities changed.** List of the activities which is presented in section 3.2.2 has been changed comparing to the list we originally presented in our protocol. At first, we only included architecture activities. When we started extracting data from our selected papers we realized many of the papers address other types of activities rather than architecture activities. Therefore, we decided to add several activities including: "Implementation and Integration", "Testing", "Requirement", and "Maintenance" to our list. We also combined two activities "Architecture documentation" and "Architecture description" into one activity.
- **Combining certain quality (score) questions.** Originally, we had nine questions for quality scores. After careful considerations, we realized that answers of two questions do not actually add any value to our data, and we decided to combine certain similar questions and reduce them to seven questions.

3. Results

We used the data extraction form introduced in section 2.5 to extract relevant information from studies that we identified through our search process (see section 2.3). This information assisted us in answering our research questions. In the following sections, first we give an overview of the identified studies and extracted information. Then, we answer the research questions one by one by analyzing the information relevant to each question.

3.1. Results overview and demographics

We searched 6 electronic databases which initially led to 11346 papers. After performing several filtering phases based on inclusion and exclusion criteria (see previous section) we reduced the number of papers to 50. When we were reading these 50 papers, we found two duplicated papers, and one paper being only an abstract (missed during the filtering based on inclusion and exclusion criteria). Therefore, we excluded these papers from our study. Moreover, we could not access one particular paper titled “Increasing business flexibility and SOA adaption through effective SOA governance” through any of the electronic libraries. We directly contacted the author to get the paper, but we did not succeed. Finally, we analyzed 46 of the 50 original papers (see appendix D).

Figure 3 indicates how many papers were published per year between January 1, 2000 and 20th of February of 2011, and how many of them were found in journals or conferences. According to figure 3, first papers started to appear in 2004 and then the number of publications increased over time until 2009. Comparing to 2009, in 2010 the number of published papers decreased. As our search stopped in February 2011, there are no papers for 2011. Figure 3 also shows that only 8 papers out of 46 were found in journals and they were mostly published in 2008 and 2009. Furthermore, Figure 3 shows an interesting trend of published papers: Compared to studies on variability management in general and publications related to software product line engineering, there seems to be a shift of 4-5 years before researchers started to investigate variability in QA in service-based systems.

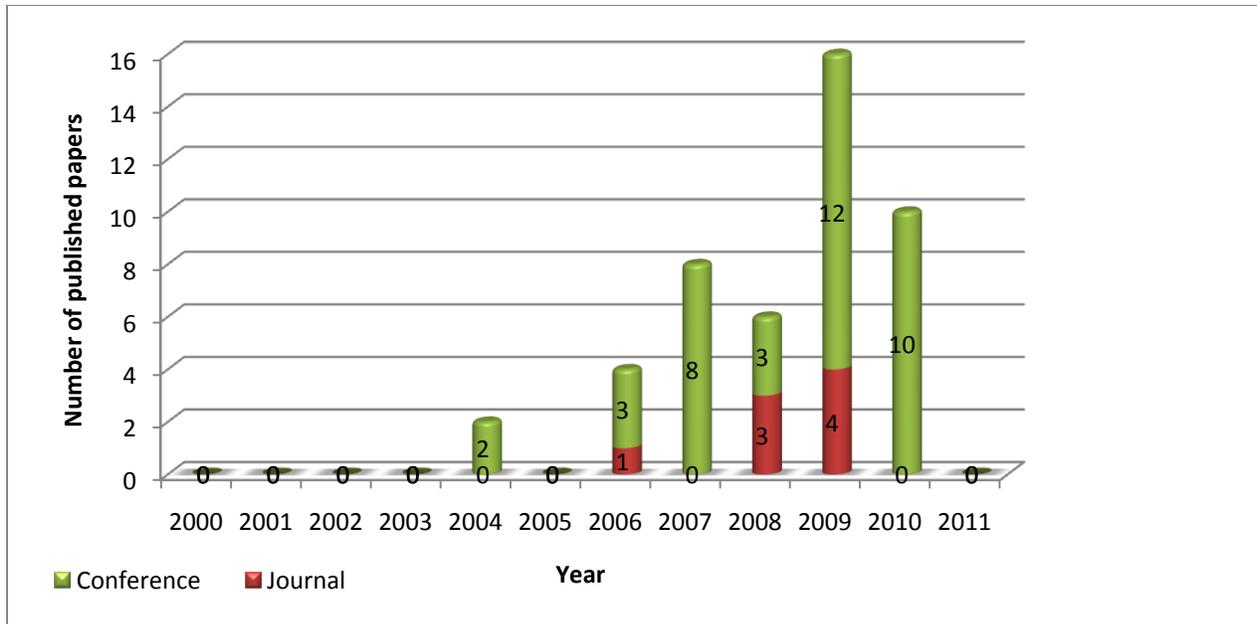


Figure 3- Publications per year.

Table 9 contains all our assessed papers, their venues, and runtime quality attributes. Since our reviewed papers do not address significant design time QAs (only cost is addressed), we do not list any design time QA in table 9. We will discuss design time QAs in section 3.2.1.2 in detail. Note that, our goal was to find studies which discuss variability of quality attributes. However, after reading the papers we realized 8 of them do not explicitly address any quality attributes (see section 3.2.1.1). Despite the fact that these studies do not specifically address any QAs, they still consider the issue of variability and handling of QAs. Therefore, we decided not to eliminate these studies from our research.

We tried to categorize venues in which our selected papers were published and assign them to certain topics such as software engineering, computer science, etc. to check if there is a correlation between our selected papers and certain research topics.

Table 9- Assessed papers with titles, sources and addressed runtime QAs.

Study	Title	Source	Runtime QA
S1	Self-optimizing architecture for ensuring quality attributes in the cloud	2009 Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture, WICSA/ECSA 2009	Performance, Availability, Reliability
S2	Variation Oriented Service Composition and Adaptation (VOSCA): A Work in Progress	IEEE International Conference on Services Computing SCC 2007 (2007)	No specific QA
S3	A trust type based model for managing QoS in Web services composition	2007 International Conference on Convergence Information Technology, ICCIT 2007	Availability, Reliability, Response time
S4	AN INTELLIGENT CONTROL ARCHITECTURE FOR ADAPTIVE SERVICE-BASED SOFTWARE SYSTEMS	International Journal of Software Engineering and Knowledge Engineering	Performance
S5	Adaptive Quality of Service Management for Enterprise Services	ACM Transactions on the Web	Performance, Availability

S6	Towards Composition as a Service – A Quality of Service Driven Approach	Data Engineering, 2009. ICDE '09. IEEE 25th International Conference on	Availability, Reliable Messaging, Throughput response time,
S7	QoS Decomposition for Dependable Service-Oriented Middleware	2009 ISECS International Colloquium on Computing, Communication, Control, and Management	Availability, Response time, Reliability
S8	Quality of Service Composition and Adaptability of Software Architectures	Proceedings of the 2009 IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing, ISORC 2009	No specific QA
S9	Uncertainty-aware QoS Description and Selection Model for Web Services	Proceedings - 2007 IEEE International Conference on Services Computing, SCC 2007	Response time
S10	Designing a broker for QoS-driven runtime adaptation of SOA applications	ICWS 2010 - 2010 IEEE 8th International Conference on Web Services	Response time, Availability
S11	Template based SOA framework for dynamic and adaptive composition of Web Services	Networking and Information Technology (ICNIT), 2010 International Conference on	No specific QA
S12	An OptimalAgent-Based Architecture for Dynamic Web Service Discovery with QoS	2010 Second International conference on Computing, Communication and Networking Technologies	Response time, Throughput, Availability
S13	QoS Oriented Web Service Composition and Optimization in SOA	2009 Joint Conferences on Pervasive Computing, JCPC 2009	Response time, Throughput
S14	An adaptive algorithm for QoS-aware service composition in grid environments	Service Oriented Computing and Applications, 2009 - Springer	Throughput
S15	A QoS-Aware Middleware for Fault Tolerant Web Services	2008 19th International Symposium on Software Reliability Engineering (ISSRE)	Reliability
S16	A Web Service Architecture Providing QoS Management	Web Congress, 2006. LA-Web '06. Fourth Latin American	Response time, Throughput, Availability, Reliability
S17	QoS-aware Selection of Web Services Based on Fuzzy Partial Ordering	2009 International Conference on E-Business and Information System Security, EBISS 2009	Availability, Response time
S18	QoS-driven Runtime Adaptation of Service Oriented Architectures	ESEC-FSE'09 - Proceedings of the Joint 12th European Software Engineering Conference and 17th ACM SIGSOFT Symposium on the Foundations	Reliability, Performance
S19	Flow-Based Service Selection for Web Service Composition Supporting Multiple QoS Classes	Proceedings - 2007 IEEE International Conference on Web Services, ICWS 2007	Availability, Response time
S20	Adaptive Application-Specific Middleware	Proceedings of the 1st workshop on Middleware for Service Oriented Computing	Performance
S21	A New Approach for Tracing Quality Attributes in Service Oriented Architecture Using Graph Transformation Systems	Computer Conference, 2009. CSICC 2009. 14th International CSI	Security, Performance
S22	GOS: A Global Optimal Selection Approach for QoS-Aware Web Services Composition	2010 Fifth IEEE International Symposium on Service Oriented System Engineering	Availability, Response time
S23	Developing Service-based Software Systems with QoS Monitoring and Adaptation	Proceedings of the IEEE Computer Society Workshop on Future Trends of Distributed Computing Systems	Timeliness, Throughput, Security
S24	Toward a Simulation-generated Knowledge Base of Service Performance	Proceedings of the 4th Workshop on Middleware for Service Oriented Computing, MW4SOC 2009 held at the ACM/IFIP/USENIX International Middleware Conference	Performance
S25	A QoS-aware Model for Web	2009 First International Workshop on Education	Response time,

	Services Discovery	Technology and Computer Science	Availability
S26	An Efficient QoS-driven Service Composition Approach for Large-scale Service Oriented Systems	IEEE International Conference on Service-Oriented Computing and Applications, SOCA' 09	Response time, Throughput
S27	TOWARDS AN AUTONOMIC SERVICE ORIENTED ARCHITECTURE IN COMPUTATIONAL ENGINEERING FRAMEWORK	10th International Conference on Information Science, Signal Processing and their Applications (ISSPA 2010)	No specific QA
S28	A new approach for QoS-aware web service composition based on Harmony Search algorithm	2009 11th IEEE International Symposium on Web Systems Evolution, WSE 2009	Response time, Availability, Reliability
S29	Requirements for QoS-Based Web Service Description and Discovery	IEEE Transactions on Services Computing	Availability, Reliability, Performance
S30	An Integrated Tool for Trade-off Analysis of Quality-of-Service Attributes	Proceedings of the 2nd International Workshop on the Quality of Service-Oriented Software Systems	Performance, Reliability
S31	QoS-based Dynamic Web Service Composition with Ant Colony Optimization	2010 IEEE 34th Annual Computer Software and Applications Conference	Availability, Response time, Reliability
S32	Toward Development of Adaptive Service-Based Software Systems	IEEE Transactions on Services Computing	Performance
S33	Dynamic Policy-Driven Quality of Service in Service-Oriented Systems	2010 13th IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing	Performance, Reliability
S34	Scalable Adaptive Web Services	Proceedings - International Conference on Software Engineering	Performance
S35	Integrated Quality of Service (QoS) Management in Service-Oriented Enterprise Architectures	Proceedings. Eighth IEEE International Enterprise Distributed Object Computing Conference, 2004. EDOC 2004.	Performance, Reliability, security
S36	Aspect-oriented Approach for Non-functional Adaptation of Composite Web Services	2007 IEEE Congress on Services (Services 2007)	Security
S37	Variation-Oriented Analysis for SOA Solution Design	SCC 2007. IEEE International Conference on Services Computing, 2007	No specific QA
S38	A Constraint Satisfaction Approach to Non-functional Requirements in Adaptive Web Services	International Conference on Next Generation Web Services Practices	Availability (different definition from our definition)
S39	Modeling the Variability of Web Services from a Pattern Point of View	European Conference on Web Services -Lecture Notes in Computer Science, 2004, Volume 3250/2004	No specific QA
S40	Towards a Variability Model for SOA-Based Solutions	2010 IEEE International Conference on Services Computing	No specific QA
S41	A Scalable and Highly Available Brokering Service for SLA-Based Composite Services	International Conference on Service-oriented Computing -Lecture Notes in Computer Science, 2010	Availability
S42	A framework for QoS-aware binding and re-binding of composite web services	The Journal of Systems and Software 81 (2008) 1754–1769 www.elsevier.com/locate/jss	Response time
S43	EASY: Efficient semAntic Service discoverY in pervasive computing environments with QoS and context support	The Journal of Systems and Software 81 (2008) 785–808	Security, Performance, Reliability

S44	Flexible Automatic Service Brokering for SOAs	10th IFIP/IEEE International Symposium on Integrated Network Management 2007, IM '07	Availability, Performance
S45	Extensible Contract Broker for Performance Differentiation	International Workshop on Software Engineering for Adaptive and Self-Managing Systems (SEAMS '07)	Performance
S46	QoS-Aware Composite Services Retrieval	JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY, Volume 21, Number 4, 547-558	No specific QA

After considering the venues in which our results were published, we decided to group the venues into four main categories for further analysis. Practically, we used venues' titles to come up with the categories. Most of the venues include explicit terms such as Software engineering, Service-oriented, Distributed system, Computer science, Networking, etc. which led us to decide on having four main categories. By having four categories, all the venues could be assigned to one particular category. However, there were several venues with vague names that we could not assign them to any of the categories. Therefore, we looked up venues web sites to see what kinds of papers they publish and how they describe themselves; then we assigned them to a specific category. After all, still there is a fuzzy line between the categories, and one may assign one venue to different categories, but we tried to assign them to best fitted categories. The categories and the assigned venues are shown in table 10.

Table 10- Venue categories.

Category	Assigned venues
Software engineering	<ul style="list-style-type: none"> • Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture(WICSA/ECSA - 2009) • International Journal of Software Engineering and Knowledge Engineering (IJSEKE) • ACM Transactions on the Web • International Conference on Data engineering(ICDE) • Joint Conferences on Pervasive Computing (JCPC) • International Symposium on Software Reliability Engineering (ISSRE) • Latin American Web congress(LA-Web) • Joint European Software Engineering Conference and ACM SIGSOFT Symposium on the Foundations (ESEC-FSE and ACM SIGSOFT) • IEEE Computer Society Workshop on Future Trends of Distributed Computing Systems • Computer Software and Applications Conference (COMPSAC) • International Conference on Software Engineering(ICSE) • IEEE International Enterprise Distributed Object Computing Conference (EDOC) • Journal of Systems and Software (JSS) • International Workshop on Software Engineering for Adaptive and Self-Managing Systems (SEAMS) • IEEE International Conference on Services Computing(SCC) • IEEE Transactions on Services Computing • Services • IEEE International Conference on Web Services (ICWS) • IEEE International Symposium on Web Systems Evolution (WSE) • International Conference on Next Generation Web Services Practices (NWeSP)

	<ul style="list-style-type: none"> • European Conference on Web Services-Lecture Notes in Computer Science • IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing (ISORC) • International Conference on Service Oriented Computing and Applications (ICSOC) • Workshop on Middleware for Service Oriented Computing (MW4SOC) • IEEE International Symposium on Service Oriented System Engineering (SOSE) • International Workshop on Education Technology and Computer Science (ETCS) • IEEE International Conference on Service-Oriented Computing and Applications (SOCA) • IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing (ISORC)
Computer science and Information technology	<ul style="list-style-type: none"> • International Conference on Convergence Information Technology (ICCIT) • International Colloquium on Computing, Communication, Control, and Management (ISECS) • International Conference on Networking and Information Technology (ICNIT) • JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY
Networking	<ul style="list-style-type: none"> • International conference on Computing, Communication and Networking Technologies (ICCCNT) • IEEE International Symposium on Integrated Network Management (IM)
Other	<ul style="list-style-type: none"> • International Conference on E-Business and Information System Security (EBISS) • International CSI Computer Conference (CSICC) • International Conference on Information Science, Signal Processing and their Applications (ISSPA) • International Workshop on the Quality of Service-Oriented Software Systems (QUASOSS)

Each of these main categories may include a number of sub-categories. Again, we used venues' titles to come up with the sub-categories. Most of the venues include explicit terms such as Service-Oriented Computing and Applications, Services and Service Computing, and Web services. The rest of papers which did not fall into any of the mentioned sub-categories are assigned to "Others" sub-section. Sub-categories of Software engineering is indicated in table 12. Table 11 indicates the main categories and the number of papers that were published in that particular venue category.

Table 11- Four main venue categories.

Venue Category	Number of papers published
Software engineering	35
Computer science and Information technology	5
Communication and Networking	2
Others	4

76% (i.e., 35 papers) of the results were published in venues on general topics of Software Engineering. Among them 57.3% were published in venues about Services, Service-Oriented Computing and

Applications, and Web Services, and the 42.7% of the rest were published in a variety of venues with different topics such as pervasive computing, and data engineering, distributed computing systems (for venues see table 10).

Table 12- Sub-categories of the software engineering category.

Venues	Percentages of papers published
Services, Service-Oriented Computing and Applications, and Web Services	57.3% (i.e., 20 papers)
Other topics of SE	42.7% (i.e., 15 papers)

After Software Engineering, most of the results (10.9%, i.e., 5 papers) belong to the Computer Science and Information Technology category. Finally, venues on Communication and Networking possess only 4.4% (i.e., 2 papers) of our results. The rest of results (8.7%, i.e., 4 papers) include papers from different venues such as E-Business and Information System Security, and Signal Processing and their Applications (see figure 4).

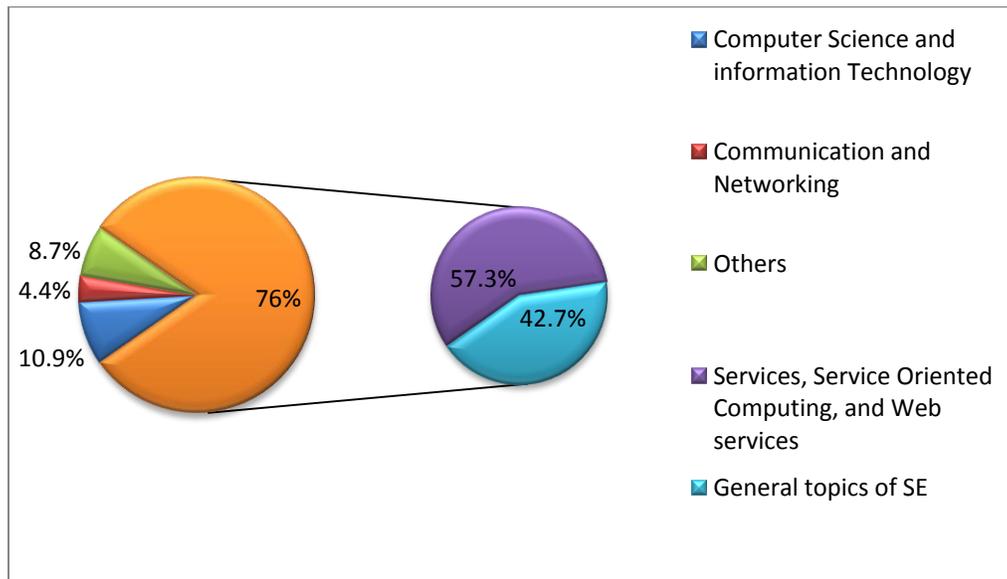


Figure 4- Distribution of papers per venue categories.

Based on our analysis which is briefly shown in figure 4, most of the papers we used in our study were published in the category of Software Engineering and least of them belong to the domain of communication and networking. Among different topics included in the Software Engineering category, venues on services, service-oriented computing, and web services has the most number of papers in our study (57.3%), which means this research community, not surprisingly, is more focused on the issue of variability of QAs compared to research communities which are active in other general topics of Software Engineering. The rest of publications (42.7%) belong to a vast variety of venues, and they are all listed in table 10.

3.2.RQ1: What methods to handle variability in QA in service-based systems exist?

To answer this question we assessed and analyzed the related data of the fields F9 (Method proposed), F10 (Nature of solution), F11 (Domain), F12 (Runtime QAs), F13 (Design time QA), and F15 (Development activities addressed) from data extraction form (see section 2.5).

3.2.1. RQ1.1: What types of variability do these methods handle?

In two following sections we provide analysis for runtime and design time QAs which are addressed by the studies.

3.2.1.1. Runtime quality attributes

Table 13 indicates runtime QAs, and the number of papers which addressed the QAs.

Table 13- Runtime QAs addressed by assessed studies.

QAs	Number of papers addressed QAs	Study identifiers
Performance	34	S1, S3, S4, S5, S6, S7, S9, S10, S12, S13, S14, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S28, S29, S30, S31, S32, S33, S34, S35, S42, S43, S44, S45
Availability	18	S1, S3, S5, S6, S7, S10, S12, S16, S17, S19, S22, S25, S28, S29, S31, S38, S41, S44
Reliability	15	S1, S3, S6, S7, S15, S16, S17, S18, S28, S29, S30, S31, S33, S35
Security	5	S21, S23, S35, S36, S43

Being addressed by 34 papers, performance is the most addressed QA. On the other hand, security is the least addressed QA, being only addressed by 5 papers. After performance comes availability and reliability, and they are considered by 18 and 15 papers, respectively. Table 9 details what studies address which runtime quality attributes.

We were curious to know if the studies have a tendency to consider specific sets of QAs along with each other in their proposed variability handling methods or not. Therefore, we listed all the possible sequences of QAs and the number of papers addressed these sets of QAs in table 14. Note that in table 14 number of papers assigned to each of the QAs is different from the numbers provided in table 13. The reason is that we count each QA only once. It means if a quality attribute appears in one QAs set relating to a particular paper, we will not count it again as a single QA addressed by that particular paper.

Table 14- Possible sets of runtime QAs and the number of papers addressing these QAs sets.

QAs combinations	Number of papers addressed QAs
Performance	11
Availability	2
Reliability	1
Security	1

Performance and A vailability	7
Performance and R eliability	3
Performance and S ecurity	2
A vailability and R eliability	0
A vailability and S ecurity	0
R eliability and S ecurity	0
Performance and A vailability and R eliability	9
Performance and S ecurity and R eliability	2
A vailability and R eliability and S ecurity	0
Performance and A vailability and R eliability and S ecurity	0
None	8

Clearly, after **Performance (P)**, which is addressed by 24% of assessed studies, 19.5% of the methods can handle variability of **Performance and Availability and Reliability (PAR)** QAs by their proposed solutions (see figure 5). Then comes the set including **Performance and Availability (PA)** QAs, which is addressed by 15.2% of the studies. Although some other combinations of QAs are taken into consideration by certain viability methods, but performance alone, and **PAR** and **PA**, as sets of QAs, seem to be the focus of the most of the studies so far.

From the table above it is obvious that certain QAs sets are not taken into account by any of the studies. These sets are specified by inserting 0 under “Number of papers addressed QAs”. One problem we encountered while analyzing quality attributes was the absence of definitions or poor definitions for QAs. We tried to check the meaning of the quality attributes in their context for each of the studies, but sometimes studies do not provide a clear, or any definition for their discussed quality attributes. For instance consider availability and reliability; many people consider them as the same. As a result, based on our extracted data from some papers, we could not decide which one of the quality attributes (reliability, availability) they actually meant.

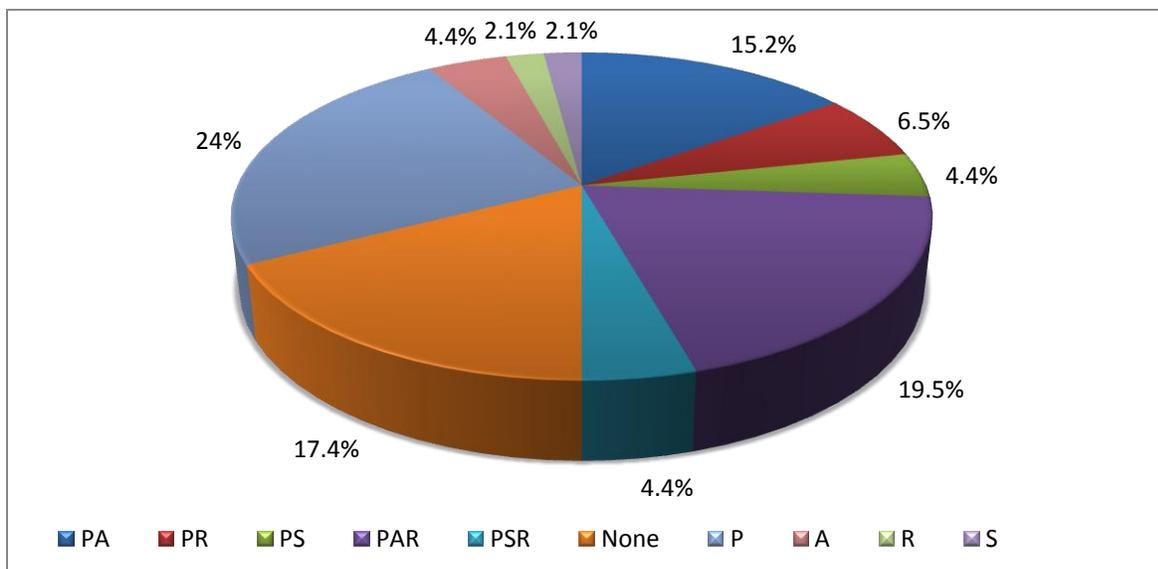


Figure 5- QA sets and their appearance in papers.

Among all the analyzed studies, 17.4% of them do not explicitly specify which of the runtime QAs are addressed by their proposed variability method. These studies confine their method to the term “Quality of Service” and only mention that QoS refers to several concepts and QAs. In the figure above these groups of studies are shown by “None”.

We can analyze these data from another angle and verify how many runtime QAs are addressed by each of the studies. Figure 6 indicates this information.

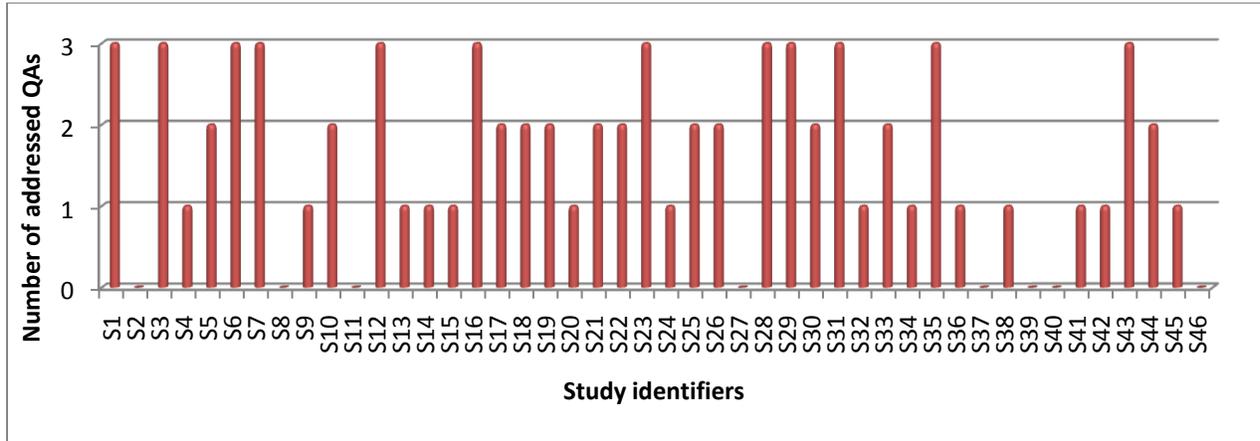


Figure 6- Number of addressed QAs per paper.

From figure above we can see that 12 papers (i.e., 26.1%) of 46 papers address three QAs, 12 papers address two QAs, 14 papers (i.e., 30.4%) address only one QA, and the rest of the papers (8 papers) do not clearly address any QA. It shows that studies mostly focus on one specific QA.

3.2.1.2. Design time quality attributes

When it comes to design time quality attributes, the only attribute which is addressed by some of studies is cost. Note that, although many studies consider cost as constraint, we consider it as QA as it is explained in S-Cube quality model [23]. 41.3% of our assessed studies (i.e., 19 papers) take into account the cost as a design time QA (see table 15).The rest of the studies (58.7%) do not consider any design time QAs.

Table 15-List of design time QAs addressed by papers.

Design time QAs	Study identifier
Cost	S1, S3, S6, S7, S12, S13, S14, S22, S24, S25, S28, S29, S30, S31, S37, S38, S40, S42, S43,

The complete table containing methods, runtime QAs, and design time QAs is provided in appendix C.

3.2.1.3. Domains of methods

In table 16 we listed our assessed studies and their domains. First of all we have to admit that it was not easy to recognize the domain of the studies, since most of the authors do not explicitly specify their domain of research. However, most of the studies acknowledge their proposed methods are useful for selecting, monitoring, and modifying services while applying web services. Based on this fact, we

assigned these studies (i.e., 14 papers), with vague research domains, to web services domain which is very generic. On the other hand, 13 studies explicitly declared their proposed methods are useful in enterprise and business applications, and e-commerce domain, 6 studies were in distributed computing domain, and 4 papers in service-oriented computing domain. In addition to the mentioned domains, we had 2 studies belong to telecommunication domain, and 3 papers belong to cloud computing, grid computing, and network-accessible services domain. We have to admit that some of the domains may overlap each other, but we assigned papers to the domains as they were specified by the authors. Note that the venue categorization we presented in the beginning of chapter 3 is just to give an overview of the results, but this categorization considers the real domain of the study in which the variability was treated.

Table 16-Reviewed studies belonging to single domain.

Domain	Number of papers	Study identifier
Web services	14	S2, S3, S7, S10 , S19, S21, S25, S28, S31, S34, S36, S43, S45, S46
Enterprise and business applications, and e-commerce	13	S5, S11, S12, S15, S16, S20, S29, S35, S38, S40, S41, S42, S44
Telecommunication	2	S8, S32
Distributed Computing	6	S4, S6, S22, S27, S33
Cloud computing	1	S1
Grid Computing	1	S14
Network-accessible services	1	S18
Service-oriented computing	4	S17, S24, S30, S37

However, table 16 does not cover full list of papers and their domains. Since certain studies were belonged to more than one domain, we listed the remaining of papers in separate table (see table 17).

Table 17- Reviewed studies belonging to multiple domains.

Domain	Number of papers	Study identifier
Web services, telecommunication	2	S9, S23
Web services, Enterprise and business applications	2	S13, S26
Telecommunication, Enterprise and business applications	1	S39

As we can see, these studies mostly were done in domain of telecommunication, enterprise and business applications.

Summary of answer to RQ1.1

To briefly answer this sub question, we can say that most of the methods presented in the reviewed studies focus on the performance of the system, while do not significantly consider design time QAs, and cost is the only design time QA which is addressed by several studies. Also, most of the studies tend to keep the domain of their research very generic and do not limit specifically define in which domain their methods handle the variability.

3.2.2. RQ1.2: What activities in the development process are addressed by the methods?

Table 18 presents all the development process activities, the number of papers addressed each of the activities, and the studies identifiers. As it is shown Architecture design (ADs) activity has been addressed by twenty studies and more than all other activities. On the other hand, several activities including Architecture analysis (AA), Architecture synthesis (AS), Architecture evaluation (AE), Architecture maintenance (AM), Architecture recovery (AR), Architecture documentation and description (ADp), and Testing (T) have not been addressed by any of our assessed studies. Those studies which are listed in “None” row do not explicitly address any activities.

Table 18- Development activities addressed in studies.

Activity	Number of papers addressed the activities	Study identifier
AA	3	S30, S37, S39
AS	0	None
AE	0	None
AM	0	None
AI	4	S10, S18, S27, S36
ADs	20	S4, S8, S10, S12, S16, S19, S20, S25, S27, S29, S32, S34, S35, S36, S37, S38, S39, S41, S44, S46
AR	0	None
ADp	0	None
AIA	1	S37
II	19	S3, S7, S11, S13, S14, S17, S19, S22, S25, S26, S28, S29, S31, S40, S42, S43, S44, S45, S46
R	3	S6, S7, S13
T	0	None
M	5	S5, S13, S15, S21, S42
None	6	S1, S2, S9, S23, S24, S33

Base on the fact that some of the studies take more than one activity into consideration, in table 18 the total number papers is 61, which is greater than the total number of studies we assessed (i.e., 46). Therefore, we present data from table 18 in another format in table 19; here we also present those activities which addressed in the same studies as sets of activities. Moreover, similar to the analysis we performed for QAs in section 3.2.1, here we were eager to see whether certain sets of development

activities were addressed more than the others by the studies or not. The difference is, due to the fact that here we have fourteen different activities, we can obtain a very long list of all the possible sequences of activities. Therefore, in table below we only included those sets of activities which were explicitly addressed by the certain studies.

Table 19-Single and sets of development activities addressed in assessed studies.

Activity	Number of papers addressed the activities
AA	1
AS	0
AE	0
AM	0
AI	1
ADs	10
AR	0
ADp	0
AIA	0
II	10
R	1
T	0
M	3
II, R	2
AD, AI	3
ADs, AA, AIA	1
AA, ADs	1
II, M	2
II, ADs	5
None	6

As a result, six different sets of activities are provided in table 19. Note that in this table number of papers assigned to each of the development activities is different from the numbers provided in the previous table (table 18). The reason is we count each activity only once. It means that if an activity appears in one activity set relating to a particular paper, then we will not count it again as a single activity addressed by that particular paper. As mentioned before, out of all 46 selected studies six of them did not explicitly consider any of the development activities, or at least based on the description provided in the papers it was not clear which activities were supposed to be addressed.

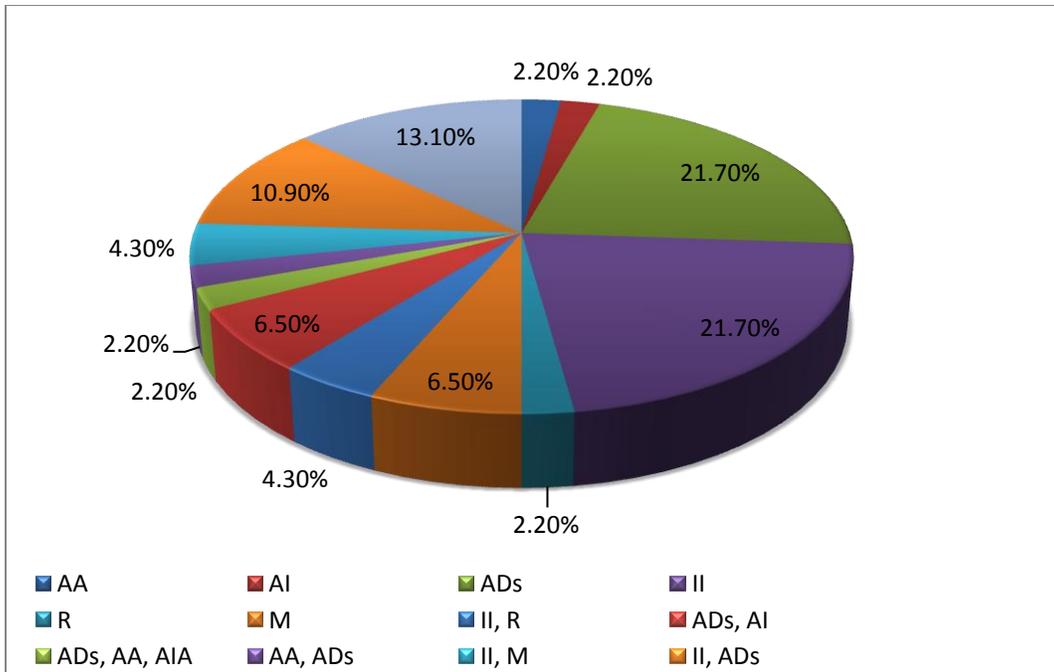


Figure 7- Development process activities sets and their appearance in papers.

As it is shown in the figure 7, among all the grouped development activities (II, ADs) is the most common set of development activity and has been considered by 10.9% of the papers, and (ADs, AA, AIA) and (AA, ADs) have the lowest popularity possessing occurrence percentages of 2.2.

From another point of view we can analyze data presented in table 19 to see how many studies addressed a single development activity and how many of them addressed multiple activities in their proposed variability method.

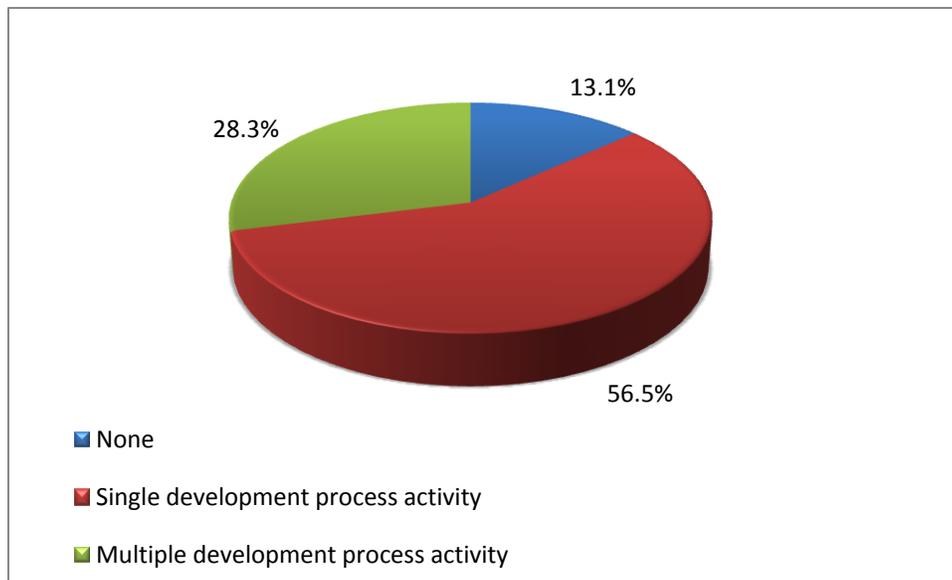


Figure 8- Papers that address none, one, or multiple development activities.

As it is indicated in figure 8, 56.5% of the studies (i.e., 26 papers) merely address one of the activities introduced in table 4, 30.4% of the studies (i.e., 14 papers) address multiple development activities, and finally 13.1% of the studies (i.e., 6 papers) address no activities.

Summary of answer to RQ1.2

The answer to this sub question would be that, majority of the studies only address a single development activity and Architecture designs and Implementation and integration are the most addressed activities by our assessed studies.

3.2.3. RQ1.3: What is the impact of the product line domain on handling variability in quality attributes of service-based systems?

In table 20, we listed all types of solutions and the number of papers used those solutions. As we can see in table 20, FM is the most common solution type among all the studies, and 13 of 46 papers use FM as their single solution type. On the other hand, SV, ON and DS are equally used by only one paper, and are the most uncommon solution types.

Table 20- Nature of proposed solutions and papers.

Nature of solution	Number of papers	Study identifier
Natural language (NL)	4	S1, S11, S16 , S33
Formal techniques based on mathematics (FM)	13	S3, S5, S9, S13 , S14, S17, S19, S22, S26, S28, S31, S40, S42
Variability as part of a technique that models services of the system (SV)	1	S2
Variability as part of a technique that models the architecture of the system (AR)	5	S8, S12, S27, S32
Ontology based techniques (ON)	1	S29
Domain-specific language (DS)	1	S6

Since some of the studies used more than one solution, we also listed all those sets of solutions which were used by certain studies and assigned them number of papers in which the solution sets were used (see table 21). Among solution type sets, AR, FM is the most common set which is used by three papers, and there are several solution sets such as (ON, FM), (FM, UM), and (SV, ON) which are used only once and by one study.

As we already anticipated in section 2.5, these solution types were not adequate and we had certain papers which used some particular solution types in addition to those we presented in table 5. We also included these solution types in the table 21.

Table 21- Solution type sets and papers using them.

Nature of solution (sets)	Number of papers	Study identifier
SV, FM	2	S7, S25
AR, FM	3	S15, S38, S46
SV, ON	1	S44
SV, NL	1	S4

AR, NL	3	S10, S20, S41
ON, FM	1	S43
NL, XML	1	S45
FM, UM	1	S18
AR, UM	1	S37
NL, UM	1	S39
AR, Model based autonomic computing	1	S34
AR, DS, An integrated QoS management architecture and its services	1	S35
A combination of UML modeling and graph transformation as a visual approach	1	S21
Controlled experiments to design model	1	S23
Simulation-based method	1	S24
Analytic Hierarchy Process based tool	1	S30

Figure 9 gives an overview of the most significant used solution types listed in both table 20 and table 21.

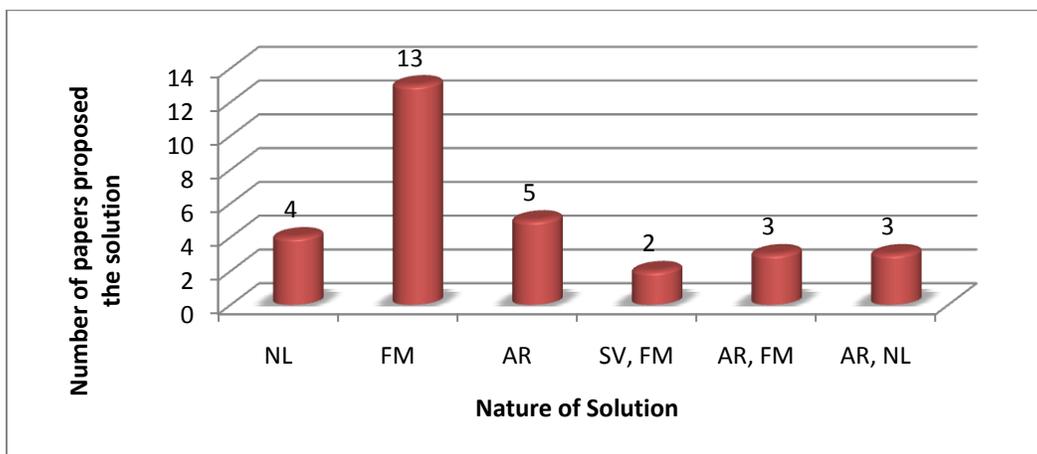


Figure 9- Solution approaches used by methods.

From another point of view, we observed that FM not only is the most common single solution type which is used by many studies (i.e., 13 papers), but it is also the most used solution type in forming solution type sets (i.e., 6 papers).

Summary of answer to RQ1.3

We can infer that most of the researchers find the FM the most effective and useful solution type among all. Together with the fact that feature modeling is almost non-existent, this shows that product line engineering do not have an impact on handling variability of quality attributes in SOA, This might be because product line engineering focuses on the modeling of features and functional requirements, instead of non-functional requirements and quality attributes.

3.3.RQ2: How much evidence is available to adopt proposed methods?

To answer this question we assessed and analyzed the related data of the fields F7 (Citation count), F8 (Quality score), F18 (Evidence level), and F19 (Evaluation approach) from data extraction form (see section 2.5).

Several factors could be used to evaluate the trustworthiness of a study. The first factor is the citation count of the publication. By counting the number of times a study has been cited in published research, we can have estimation about the impact of that study. For instance, if a study has a high number of citations, we can conclude that it has been the subject of discussion in other published studies.

We used Google scholar to gain the citation counts of our selected studies. Table 22 shows full list of papers and their citation counts, and their quality scores.

Table 22- Citation counts and gained quality scores.

	Citation count	Quality score							Total QS
		Q1	Q2	Q3	Q4	Q5	Q6	Q5	
S1	3	1	0	0	N/A	0.5	0	0	1.5
S2	1	1	0.5	0	N/A	0.5	0	0	2
S3	5	1	0.5	0	N/A	0	0	0	1.5
S4	0	1	1	0	0.5	1	0.5	0.5	4.5
S5	33	1	1	0	0.5	1	0	0.5	4
S6	23	1	1	0	N/A	0.5	1	1	4.5
S7	0	1	1	0.5	N/A	1	0	0	3.5
S8	4	0.5	0.5	0	N/A	0	0.5	0.5	2
S9	1	1	0.5	0	N/A	1	0	1	3.5
S10	6	1	1	0	N/A	0.5	0	0.5	3
S11	0	1	0.5	0	N/A	0.5	0	0.5	2.5
S12	1	1	1	0	N/A	0.5	0	0	2.5
S13	0	1	1	0	N/A	1	0	1	4
S14	3	1	1	0	N/A	1	0	1	4
S15	9	1	0	0-0.5	N/A	1	0	1	3
S16	23	1	1	0.5	N/A	1	0	1	4.5
S17	0	1	0.5	0	N/A	1	0	0.5	3
S18	26	1	1	0	N/A	1	0.5	0.5	4
S19	48	1	1	0	N/A	1	0	0.5	3.5
S20	4	1	0.5	0	N/A	1	0	0.5	3
S21	1	1	0	0	N/A	0.5	0	0.5	2
S22	0	1	0.5	0	N/A	1	0	0.5	3
S23	14	1	0.5	1	1	1	0.5	0.5	5.5
S24	4	1	1	1	N/A	1	0.5	1	5.5
S25	2	1	0	0	N/A	0.5	0	0.5	2

S26	2	1	0.5	0	N/A	0.5	0.5	0.5	3
S27	0	1	0.5	0	N/A	0.5	0	0	2
S28	0	1	0.5	0	N/A	0.5	0	0.5	2.5
S29	12	1	1	0	N/A	1	0.5	0.5	4
S30	3	1	1	0	N/A	0	0	0	2
S31	3	1	1	0	N/A	1	0	0.5	3.5
S32	8	1	1	1	1	1	0	0.5	5.5
S33	6	1	0.5	0	N/A	1	0	0.5	3
S34	7	1	0.5	0	N/A	0.5	0	1	3
S35	55	1	1	0.5	N/A	1	0	0.5	4
S36	2	1	1	0	N/A	1	0	0	3
S37	14	1	0.5	0	N/A	0.5	0	0	2
S38	5	1	1	0	N/A	1	0	0	3
S39	21	1	1	0	N/A	1	0	0	3
S40	0	1	1	0	N/A	1	0	0.5	3.5
S41	1	1	1	0.5	N/A	1	0	0.5	4
S42	61	1	1	1	N/A	1	0.5	1	5.5
S43	71	1	1	0.5	N/A	1	0.5	1	5
S44	9	1	1	0	N/A	1	0	1	4
S45	2	1	0.5	0	N/A	0.5	0	0.5	2.5
S46	5	1	1	0.5	N/A	1	0	0.5	4

By using data provided in table 22 we derived table 23; the first column indicates a list of citation counts and the second column shows how many of the papers had that specific citation count.

Table 23- Papers with citation counts.

Citation counts	Number of papers
0	9
1	4
2	4
3	4
4	4
5	3
6	2
7	1
8	1
9	2
12	1
14	2
21	1
23	2
26	1

33	1
48	1
55	1
61	1
71	1

As we can see, the lowest citation count and the highest citation counts are 0 and 71, respectively. 9 of 46 assessed papers had citation count of zero, and one papers had citation count of 71, the highest citation count. 34 papers (74%) possess citation counts in range of 0-9, and only 12 papers (24%) have high citation counts in range of 12-71.

The second factor which we used to validate the studies was quality score. Based on the description we provided in section 2.4, each study received a quality score between 0 and 7, having intervals of 0.5 (see table 22). Figure 10 shows the ratio between quality assessment scores and the number of papers gained those quality scores. As we can see, there are certain quality scores which were not assigned to any of the papers. Among them, 0 and 7 as the highest and lowest scores are the significant ones. This means that, we did not have any papers fulfilling none or all of the quality criteria. The most common score is 3, which was gained by 24% of the papers, and the rarest score is 5 which is gained by only one paper. The highest score, which is gained by four papers, is 5.5 and the lowest score is 1.5 which is assigned by two papers. To see full list of quality scores assigned to each of the studies see table 22.

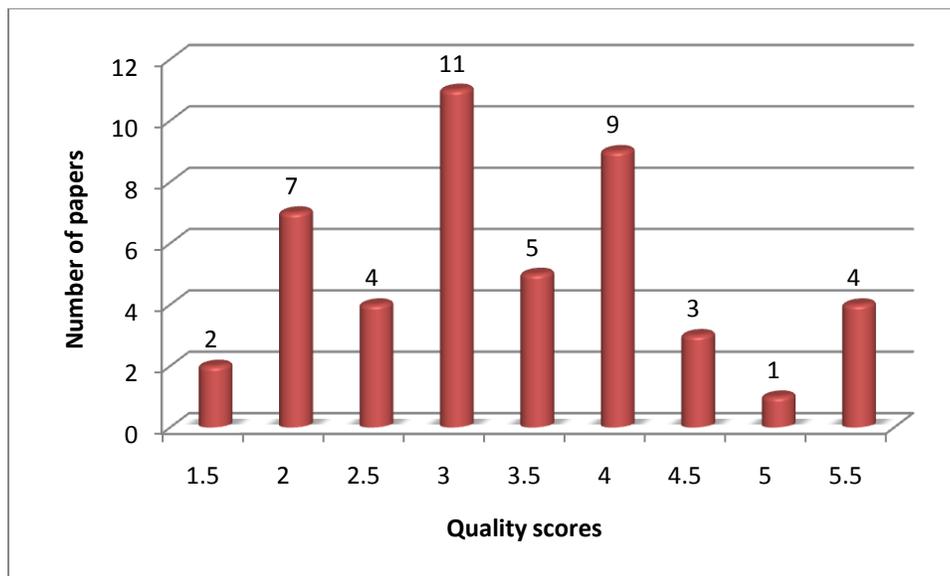


Figure 10- Quality scores of papers.

To be able to analyze the data based on the quality questions, we summarized our data in another format which is provided in table 24. First column of this table which is labeled by Q1, Q2, Q3, Q5, Q6, and Q6 represents the questions provided in section 2.4, and first row contains the scores which could be assigned to a paper to answer the questions. The numbers in the table are numbers of papers.

Table 24- Papers assigned to each score per question.

	0	0.5	1
Q1	0	1	45
Q2	4	16	26
Q3	35	7	4
Q5	3	14	29
Q6	36	9	1
Q7	11	24	11

In the following part we provide analysis for the answers we got for each of the questions:

- **Q1: Is there a rationale for why the study was undertaken?**

45 of 46 of assessed papers got score 1 answering this question. This means that almost all of the assessed papers argue why they have performed the study. Although the quality and the level of the detail for their rationale might be different, but 98% of the studies consider the reasons for their researches.

- **Q2: Is there an adequate description of the context (e.g., industry, laboratory setting, products used, etc.) in which the research was carried out?**

8.7% of the assessed studies (i.e., 4 papers) do not provide any description about the context of the research, and 34.8% (i.e., 16 papers) of the studies address this issue to some extent. However, most (56.5%, 26 papers) of the studies provide adequate description of the context, and whenever it is applicable, laboratory settings in which the research was fulfilled.

- **Q3: Is there a justification and description for the research design?**

76% of the studies (i.e., 35 papers) scored zero answering this question, and 15.3% of the studies (i.e., 7 papers) scored 0.5 which means these studies addressed the issues to some extent. Only 8.7% of the studies (i.e., 4 papers) provided justification and description for their research design.

- **Q5: Is there a clear statement of findings and has sufficient data been presented to support them?**

Although 6.5% of the studies (i.e., 3 papers) do not clearly address their findings, but 30.5% of the studies (i.e., 14 papers) to some extent and 63% of the studies (i.e., 29 papers) entirely state their findings and offer adequate data to support them.

- **Q6: Did the researcher critically examine their own role, potential bias and influence during the formulation of research questions and evaluation?**

In most (78.3%) of the studies (i.e., 36 papers) researchers do not examine their own role and possible influence during the formulation of research questions and evaluation. In 19.5% of the studies (i.e., 9 papers) researcher do pay attention to this issue, but their main concern is their role and potential

influence on the evaluation and not the formation of the research questions; only one out of 46 papers fully addressed this issue.

- **Q7: Do the authors discuss the credibility and limitations of their findings explicitly?**

24% of the studies (i.e., 11 papers) do not discuss the credibility and limitations of their findings at all, 52% of the studies (i.e., 24 papers) discuss credibility and limitations of the findings to some extent, and rest (24%) of the studies discuss this issue explicitly. The only matter is main focus of those papers which, either partially or fully, address this issue is the limitations of the proposed method in the study, and not the credibility.

The only remaining question which needs to be analyzed is **Q4**. Since the answer to this question also includes “Not applicable” option, we analyze this question separately.

- **Q4: Does the study provide description and justification of the data analysis approaches?**

91.4% of the approaches (i.e., 42 papers) provided in the assessed studies do not include any data analysis and we do not assign them any score, instead we mark the as not applicable (N/A). 4.3% of the studies (i.e., 2 papers) include data analysis approaches, but do not fully describe and justify the approaches. 4.3 of the studies (i.e., 2 papers) completely describe and justify their offered data analysis approaches (see table 25).

Table 25- Papers assigned per answers of Q4.

	N/A	0.5	1
Q4	42	2	2

The third factor we used to check the credibility of the studies was evidence level (EL) which is described in section 2.5. Table 26 contains all the evidence levels and the number of papers which used that particular evidence levels to evaluate the evidence level of their proposed methods. Since certain studies go beyond the evidence level and provide additional evidence using additional methods, we also included those two sequences of methods which were used by these studies in this table.

Table 26- Papers assigned to evidence levels.

Evidence levels	Number of papers using specific EL	Study identifier
1	10	S3, S13, S17, S21, S25, S28, S30, S33, S34, S41,
2	26	S1, S2, S6, S8, S9, S10, S11, S12, S14, S16, S18, S19, S20, S22, S23, S26, S31, S32, S35, S36, S37, S39, S40, S44, S45, S46,
3	1	S29
4	3	S15, S24, S42
5	1	S27
6	1	S38
2,3	1	S5
2,4	3	S4, S7, S43

91.3% of the studies only use one of the classified evidence levels, and 8.7% of the studies use two classified evidence levels to evaluate the evidence level of their proposed methods.

According to table above, 26 of the papers (56.5% of the studies) used evidence level number two. This means that most of the studies obtained their evidence from demonstration or working toy examples. Evidence levels number 3, 5, and 6 are each equally used only in one study and are rarest. This means very few of the studies use expert opinions or observations, industrial studies and evidence to obtain evidence level of their proposed methods.

The last factor we used to check the validity of the studies was to see whether the studies have provided evaluation of their proposed variability approaches or not. Therefore, we listed all the used evaluation methods we presented in table 8, number of papers used them to evaluate their methods, and studies identifiers in table 27. Since some studies used more than one evaluation approach in their analysis, we also listed all those sets of approaches which were used by certain studies. Those studies (i.e., 9 papers) which did not include any evaluation are listed in row labeled as “None”. Note that FE and LH were not use by any of our assessed studies.

Table 27- Papers assigned to evaluation approaches.

Evaluation approach	Number of papers used specific approach	Study identifier
DC	4	S1, S2, S6, S8
RA	2	S3, S19
SI	9	S4, S11, S14, S18, S23, S26, S31, S32, S35
EA	6	S9, S13, S20, S34, S44, S45
LS	8	S10, S15, S22, S29, S33, S41, S43, S46
EP	2	S16, S24
CS	2	S17, S21
CS, SI	1	S7
LS, DC	1	S5
LS, RA	1	S28
RA, EA	1	S42
None	9	S12, S25, S27, S30, S36, S37, S38, S39, S40

From the table 27 we can see that 80.3% of the studies (i.e., 37 papers) use one or more evaluation approaches to evaluate the credibility of their proposed methods. 33 of these 37 papers only use one evaluation approach and the other 4 papers use two approaches to evaluate their methods. Among those papers that use one evaluation approach SI is the most used and was used by 9 papers. On the other hand, RA, EP, and CS were each equally used by 2 studies and were the most uncommon approaches. Evaluation approach sets all are only used only once and by one specific paper. The rest of the studies (19.7%) do not use any type of the evaluation approaches.

Summary of answer to RQ2

Results from section 3.3 indicates that although majority of the studies provide the reason for which they have performed the research, and also adequate description of the context, but not many of them

take into account their own role and potential influence during the formulation of research questions and evaluation. In addition, only a few papers present justification and description for their research designs (e.g., literature analysis and synthesis and aggregation of results into a new method, experiments, case studies), and perform a rigorous data analysis. By comparing quality scores and citation counts assigned to each study in table 22, we conclude that majority of the studies with citation counts over 10 got a score over 3.5. Although, this means that studies with higher citation counts are often more valuable, but it does not work other way around. We can find some studies with high quality scores and no citation counts (such as S4). We can also conclude that since most of our assessed studies use toy examples as their evidence level, which is the weakest evidence level in our defined hierarchy, the majority of the studies in this domain fail to provide trustworthiness evidence to adopt their proposed variability methods. We were also curious to know if the studies (i.e., 9 papers) with high citation counts (higher than 20) and high quality scores (higher or equal to 3.5) have used robust evidence levels or not. Therefore, we compared data from table 22 to data of table 26 and realized that only three studies (S5, S42, and S43) used convincing evidence (evidence from academic studies) for their methods. These studies might be counted as the most outstanding studies among all our reviewed papers.

3.4.RQ3: What are the limitations of current methods?

To answer this question we assessed and analyzed the related data extracted from our selected studies. F11 (Domain), F12 (Runtime QAs), F13 (Design time QA), F14 (Tool support), F16 (Limitations), and F17 (Research / practice / both) fields from data extraction form presented in section 2.5 can assist us to answer sub questions of RQ3.

Based on F16 from data extraction table 4, only 34.8% of the studies discussed their methods limitations. Table 28 gives a brief description of the variability methods limitations provided by studies. Most of the limitations are technical and domain specific, and the only common limitation is high cost in S16 and S18.

Table 28-Paper limitations.

Study identifier	Limitations
S1	Application built with this method should be resilient to the changes in cloud conditions with regard to demand, changes in types of supporting services and even organizational objectives.
S2	The maximum potential of the method is only achievable during runtime adaptation.
S3	The model includes four criteria, but it is possible to add new criteria.
S6	1) VCL is not a generic language that is able to solve all QoS-aware service composition issues. 2) VCL was developed with a special focus on QoS- aware service compositions and is not targeted to solve large- scale multi-party workflows with several interactions.
S8	Everything is formulated based on quality levels, and therefore some analyses cannot be solved. The issue is discussed vaguely.
S13	The algorithm proposed in this paper is more applicable to the service composition which has adequate web services to select and complex process structure.
S14	The method only takes into account the additive QoS parameters.
S15	Only the most important QoS properties (RTT, failure-rate, and resources) are considered in the middle- ware. Also, the proposed fault tolerance middleware can only work on stateless Web services.
S16	Extra cost

S18	1) High cost, 2) This approach only takes into account fail-stop failure model. 3) It only manages composite services whose orchestration pattern matches with the presented patterns in the paper.
S20	1) This approach is limited to domains that do not involve high loads or require rapid response times. 2) Introduced middleware only deals with “internal” contracts between roles within the organizational boundary.
S24	The simulation component (wsdl2sim) has limitations: 1) Only simple types are supported for messages. 2) Is only useful for one-to-one simulation (where every operation in the web service has a corresponding object in the simulation).
S29	To exploit the full functionality of the proposed broker, the web service providers and requesters should use a set of tools
S34	1) A limited number of workloads are considered by the control scheme. 2) All control schemes have addressed individual web services; there is no general theory on how to combine multiple autonomic loops. 3) Limited accessibility to metrics.
S40	1) The service variant should possess the same set of “minimum required” inputs and outputs as the original service. 2) The service variant should retain the “integrity” of the original service.
S42	For QoS variability further analyses are needed to assess whether the proposed binding/re-binding approach is robust enough under different network and server configurations/load status. They limited the analyses to risks concerned with the increase of QoS variability for individual services, impacting on the overall process QoS variability.

3.4.1. RQ3.1: Are methods only applicable to certain types of variability?

To answer this research question we can use the analysis from previous sections as follows:

Summary of answer to RQ3.1

When we were analyzing runtime quality attributes in section 3.2.1.1., we already saw that 26.1% of the our studies (i.e., 12 papers) address three QAs, same number of papers (i.e., 12 papers) address 2 QAs, 30.4% of our studies (i.e., 14 papers) address only one QA, and the rest of the studies (i.e., 8 papers) do not explicitly address any quality attribute. In section 1.1.2., we mentioned that we will keep all the studies that address any type of QAs, and we will not exclude them from our research. However, among our assessed studies, those that address any QA, only discuss performance, availability, reliability, and security. By considering S-Cube, which offers a reference model intending to provide the S-Cube consortium with a unified terminology for describing different quality attributes of service-based applications [23], we notice that there are plenty of relevant quality attributes to the context of service-based system, but no study takes them into account. The same applies to design time quality attributes. In section 3.2.1.2., we saw that only 19 studies address design time quality attributes, and the only QA which is addressed is cost. This leads us to conclude that design time QAs are almost non-existent when it comes to handling variability, and service-based systems may not be that different from non-service-based systems when it comes to variability in design-time QA. In addition, as we discussed in section 3.2.3., most of the studies (i.e., 14 papers) intend to keep the domain of their research generic, and describe that their proposed variability methods are applicable in the domain of web services.

3.4.2. RQ3.2: Are there no practitioner-based guidelines?

Table 29 indicates how many of our assessed studies include research work, practical work or both. Although many studies used simulations, experiments and examples to explain or evaluate their proposed methods, here by practice we mean implementation of the proposed method in an industrial level, or the context in which the study was conducted (it may or may not include tool support).

Table 29-Papers assigned to research/practice/ or both.

	Number of Papers	Study Identifier
Research	42	S1, S2, S3, S4, S6, S7, S8,S9, S11, S12, S13, S14, S15, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S38, S39, S40, S41, S42, S43, S44
Practice	0	
Both	4	S5, S10, S16, S27

As it is shown, there is no study that presents pure practical work, and only four studies include both research and practice. Most of the studies (42) only include research; this indicates that researchers have been mainly focused on the academic and theoretical aspects of this topic, and not much effort has been put on the implementation and actual use and practical relevance of the proposed methods.

Table 30 indicates all the studies which provided tool support for their proposed methods. Overall, 34.8% of the studies have tool support and the rest of the studies do not provide any tool support, neither for implementation of the method nor for evaluation.

Table 30-Papers that provide tool support, and brief tool descriptions.

Study Identifier	Tool support
S5	ServiceGlobe(AutoGlobe component)
S6	Microsoft Oslo Toolkit
S7	Graphic Process Manager (Register Admin console, and Monitor console)
S8	UML, Eclipse Modeling Framework
S10	MOSES version 1 and 2 developed in this paper (components of the first version have been developed in Java as Web services, and the second version is developed using OpenESB)
S18	MOSES prototype tool
S20	Application-specific middleware can be created using the ROAD (Role-Oriented Adaptive Design) framework, which is a set of abstract Java classes used to define adaptable software “organizations.”
S21	Visual tools such as FUJABA or Murφ Model Checker can take the model as input and implement the method for tracing quality attributes.
S24	Text analysis toolkit (TAPoRware)
S27	Visualization, Modeling and Simulation software
S30	AHP Wizard
S39	Statistical Analysis System
S40	IBM’s Rational Software Architect modeling tool
S41	httperf (can be used for measuring the performance of Web servers for experiment)
S42	Discovery tool (for service search), Proxy Generator tool (for creation and deployment of the Proxy service)
S44	WSDL2JAVA tool (to automatically create a service stub for the discovered Web Service)

Although all of studies indicated in table 30 have tool supports, there are some differences among them. First, unlike most of the studies like S21 and S24 that specify the supporting tool, some studies such as S27 and S39 do not particularly specify the tool. These studies (S27 and S39) just mention that Visualization, Modeling and Simulation software, and Statistical Analysis System could be used while implementing the methods. Second, studies like S10 and S18 have developed the tools to support their proposed methods, but most of other studies, such as S40 and S8 use the tools and software which are

already available. And the last difference is related to the tools themselves, each of them has been used for a particular purpose. To give an example, in S42 and S44 tools are used to implement certain parts of the system, in S41 the tool is used to measure the performance of the system, and in S7 the tool is used to administrate and monitor the implemented system.

From another point of view, by comparing table 29 and table 30 we can see that three out of four studies that include both research and practice (S6, S10, S27), also provide tool support, and only one (S16) does not offer tool support.

Summary of answer to RQ3.2

In general, based on the fact that only 2 of our reviewed studies include practical work, and a limited number of studies provide tool supports for their proposed methods, we might conclude that there is a lack in practitioner-based guidelines.

4. Discussion of results

This chapter highlights and summarizes the main finding of our research and tries to provide recommendations whenever it is possible.

- **Focus of studies on certain QAs and ambiguity in addressed quality attributes.** Results from section 3.2 indicate that main focuses of reviewed studies are certain types of quality attributes, especially on performance. Although several types of relevant quality attributes do exist in the domain of software engineering and service-oriented computing, most of the variability methods emphasis is on performance, availability, and, reliability; and some studies use reliability and availability terms interchangeably.
- **Nature of solutions of variability methods.** Based on the fact that the product line domain is one of the research domains which is focused on variability issues, and feature modeling is one of the well-known used methods in product line engineering, we were expecting to find some studies which use feature modeling in their proposed solutions. However, based on the results from 3.2.3 none of our reviewed studies use feature modeling. Instead, most of the studies use formal techniques, which are based on mathematics, as their solution types. This shows that product line engineering and related paradigms seem to have only little impact on our research domain. This might be because product line engineering focuses on the functional requirements, instead of non-functional requirements and quality attributes. Therefore, popular methods used in the PL domain, such as feature modeling, might be of no help for variability of QA in service-based systems.
- **Poor evidence of proposed methods.** Results from section 3.3 shows that most of those reviewed studies that actually do provide evidence for their offered methods, get their evidence from demonstration or working out toy examples which is the weakest evidence level in our presented hierarchy of evidence levels. Although toy examples help comprehend the methods, having no industrial evidence is an indication that the method has not been approved and adopted by any industrial organizations yet.
- **Current status of the research in this domain and implications for practitioners.** Results from 3.4.2 indicate that not many of reviewed studies have developed tools, particularly, to support implementing their proposed methods. In addition, lack of practical research context and not providing convincing proofs for methods are obstacles for practitioners interested in adopting proposed methods. This can be a reason why these methods are not used in industrial settings.
- **Research direction for future work in the domain.** Since only a few of the QAs introduced in S-cube reference model are addressed in current studies, our first suggestion for researchers is to develop a better and more compatible quality attribute reference model for service-based domain. Second, we suggest that researchers focus on enhancing the robustness of their methods instead of inventing new methods to handle variability. For instance, they may try to implement their methods in industrial environments to evaluate their method practically. This also provides guidelines for practitioners, and motivates them to start using the methods. Furthermore, we see a need for more empirical studies.

5. Problems faced during the review, limitations and threats to validity

During our research, we faced different types of problems. Some of them happened during searching phase and others occurred while we were analyzing our extracted data. In the following sections we describe these problems and limitations and depict how we handled them.

5.1. Problems encountered during searching phase

Searching electronic databases is not a difficult task by nature, but search engines and reference management tool limitations caused unforeseen problems. In addition, we got a very huge amount of studies in our first automatic search results and we had to find an optimal way to filter and reduce them. In the following, we describe these problems and our solutions.

Search engines limitations and volume of results in automatic search phase. Each of the search engines had particular options and features. Some of them, such as Scopus, were more user-friendly and had several search options, while others, such as SpringerLink, were very simple and difficult to work with. One of the problems was with the number of papers citations we could download at once. Each of the engines allows downloading only a certain number of citations at once, therefore, we had to split the citations into parts and repeat the downloading. This was partially solved by using other features of the search engines and limiting the search to, for instance, certain publication years or topics to reduce the amount of results and reducing the downloading times. However, some of the engines, such as IEEE Xplore do not provide many options to restrict the search. As a result, searching these libraries and downloading citations from IEEE Xplore and similar libraries was very time consuming and tedious. The method we used to search these libraries was to manually filter the irrelevant papers from the beginning and not downloading the citations. Although this method helped reduce the number of times we downloaded citations, it took so much time and energy to check all the search results one by one and decide if they were irrelevant or not. The aforementioned methods not only helped reduce the downloading time, but also helped reduce the volume of results. However, the automatic search phase took more time than what we had scheduled and the volume of final automatic search result was significantly bigger than what we expected, therefore we had to speed up other phases of our SLR.

Reference manager tool limitations and errors. We used Mendeley desktop version 0.9.9.2 beta as our reference manager tool. Although this version of Mendeley works fairly good for a free version, it also had various bugs including sync library errors and common crashes when synchronizing, several crashes when using the merge or not duplicate buttons, citation formatting problems, randomly blocking certain PDFs, and failing to highlight empty PDFs or papers with no abstract. Among all, common crashes and blocking the PDFs, which made us to re-download or add some papers to the Mendeley over and over again, were the most time consuming and annoying problems. Basically, Mendeley problems were beyond our control and we could not do much about it. Although, a newer version of Mendeley (version 1.0.1), which was more stable compared to the previous version, was out after a while; we were in the last phases of our research and the update did not benefit us that much.

5.2.Limitations of the review and threats to validity

Inaccuracy and bias in selected papers for review. In automatic search phase our main goal was to ensure the completeness of our selected papers. As mentioned before, we manually searched a limited number of venues and determined a “quasi-gold” standard as proposed in [24]. This helped us to make sure that the search string for the automatic search resulted in all the relevant papers, and we do not miss any study. In the next phase, when the researcher was trying to exclude the irrelevant papers, although the researcher was using titles, keywords, and abstract to filter the papers, we wanted to avoid researcher’s individual bias affecting the process of paper selection. Therefore, to mitigate this problem, a second researcher was checking excluded and included papers at each iteration of paper filtering. This helped us make sure we were not excluding relevant papers from our paper pool.

Inaccuracy and bias in data extraction. As with any SLR, one of the main limitations of our review is inaccuracy in data extraction. We had some difficulties to extract relevant information from our selected papers. The majority of papers did not provide objective details with regard to several issues we needed to extract and use to answer our research questions. For instance, several papers do not explicitly mention in which domain their proposed methods can be used, or are most suitable, several papers do not explicitly refer to any specific type of development activity in their methods, and some of the studies do not provide clear definitions for each of the quality attributes they considered in their methods. In situations like these, interpretation of information was needed to get the required data out of the papers. Therefore, the researcher’s bias could affect the final extracted data. To alleviate this problem, for instance for domain, we tried to assign the papers to generic domains, or for development activities we did not assign any activity to any method unless we were sure the paper was addressing the activity; that is why some of reviewed papers do not address any activity.

About the quality attributes, all papers clearly define the meaning of performance and security, so we did not have any problem with these two QAs. However, several studies do not clearly define the meaning of availability and reliability, and because many researchers use these two terms interchangeably, or count them as one concept, we could not realize to which one of them they were actually referring. The same issues stands when it comes to answering quality criteria questions, and assigning quality scores to the papers. Since it was a very subjective matter to decide which quality score best suits each of the studies, the final score assigned to each paper can be inaccurate. Generally, to alleviate the inaccuracy of quality scores, and data extraction, the researcher and second person (expert) conducted discussions, or the expert was asked to check specific extracted data to judge researchers’ decisions on extracting subjective information out of papers.

Deviations from the procedures for systematic reviews provided by Kitchenham and Charter [43]. Although we were determined to use the guidelines provided in [43] to perform our SLR, we had deviation from their procedures. For instance, in our research a single researcher extracted the data rather than a group of researchers. Although this practice has been suggested in [31], this means that some of the data that we collected may be erroneous.

Inaccuracy in classifying venues. In section 3.1 we tried to categorize venues in which our selected papers were published and assign them to certain topics such as software engineering, computer

science, etc. to check if there is a correlation between our selected papers and certain topics. We acknowledge this type of categorization might be inaccurate to some extent. The reason is there is a fuzzy line between the categories, and one may assign one venue to different categories. To mitigate this problem, we decided to decrease the number of categories and relax the categorization.

6. Summary and conclusion

The goal of this thesis was to systematically study variability of quality attributes in service-based systems. Our aim was assessing the quality of current research, collecting evidence about current research that suggests implications for practice, and identifying trends, open problems and areas for potential improvement. We followed Kitchenham's guidelines for performing systematic literature reviews [43], and developed a peer-reviewed protocol for data collection, analysis and synthesis. Our results suggest that design-time quality attributes are almost non-existent in current approaches available for practitioners, and product line engineering as the traditional discipline for variability management has almost no influence how we deal with variability in quality attributes of service-based systems. Furthermore, current approaches proposed by the research community do not provide enough evidence for practitioners to adopt these approaches. Also, variability has mainly been studied in laboratory settings, leaving many unsolved challenges for practitioners.

Our suggestion for performing SLRs in the future is to limit the review to a selected number of venues which are particularly relevant to the domain of the research, and perform a manual search instead of automatic search. This would prevent from gaining huge number of irrelevant papers, and speed up the searching process. In addition, by limiting the review to specific and related venues, the quality of the results, and consequently, research increases.

Another option for researchers is to focus on variability of one specific QA in service-based systems, instead of a group of QAs. Our SLR showed that performance is the most addressed, and probably most important, QA in this domain. Therefore, performing a review on handling variability of performance in service-based systems can provide more useful and meticulous information on how this QA is treated in the domain.

Another option to investigate variability in QA's of service-based systems can be performing industrial reviews and collecting data on how do practitioners actually handle the issue of variability of QA in service-based systems.

Finally, to reduce the ambiguity of quality attributes definitions, which is a common problem in many studies, we propose using quality attribute scenario as it is described in [52]. By using quality attributes scenarios researchers can define the QAs concretely. This would avoid having multiple interpretations of a single QA, and therefore reduces the inaccuracy of data analysis.

References

- [1] Geertsema B. Increasing Software Product Reusability and Variability using Active Components : a Software Product Line Infrastructure Categories and Subject Descriptors. Development.336-343.
- [2] Marshall KM. Introduction to the Interaction Between Gonadal Steroids and the Central Nervous System. Current topics in behavioral neurosciences. 2011:1-8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21644249>.
- [3] Kontogogos A, Avgeriou P. An Overview of Software Engineering Approaches to Service Oriented Architectures in Various Fields. 2009 18th IEEE International Workshops on Enabling Technologies: Infrastructures for Collaborative Enterprises. 2009:254-259. Available at: <http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5159254> [Accessed June 7, 2011].
- [4] O'Brien L, Merson P, Bass L. Quality Attributes for Service-Oriented Architectures. International Workshop on Systems Development in SOA Environments (SDSOA'07: ICSE Workshops 2007). 2007;(September):3-3. Available at: <http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4273291>.
- [5] T. Erl, SOA Design Patterns. Upper Saddle River, NJ: Prentice Hall, 2009.
- [6] R. Hilliard, "On Representing Variation," Proc. Workshop on Variability in Software Product Line Architectures, ACM, 2010, pp. 312-315.
- [7] OASIS, "Reference Model for Service Oriented Architecture 1.0," 2006.
- [8] IEEE Computer Society Software Engineering Standards Committee, "IEEE Standard for a Software Quality Metrics Methodology." IEEE Std 1061-1992, 1992.
- [9] IEEE Computer Society Software Engineering Standards Committee, "IEEE Standard Glossary of Software Engineering Terminology." IEEE Std 610.12-1990, 1990.
- [10] Q. Gu and P. Lago, "Exploring Service-oriented System Engineering Challenges: A systematic Literature Review," Service Oriented Computing and Applications, vol. 3, pp. 171-188, September 2009.
- [11] V. Basili, G. Caldiera, and D. Rombach, "The Goal Question Metric Approach," in Encyclopedia of Software Engineering. vol. 1, J. J. Marciniak, Ed. New York, NY: John Wiley & Sons, 1994, pp. 528-532.
- [12] F. Bachmann and P. C. Clements, "Variability in Software Product Lines," SEI CMU, Pittsburgh, PA, Technical Report CMU/SEI-2005-TR-012, 2005.
- [13] M. Aiello, P. Bulanov, and H. Groefsema, "Requirements and Tools for Variability Management," Proc. 4th IEEE Workshop on Requirement Engineering for Services (REFS 2010), 2010, pp. 245-250.
- [14] K. Schmid and I. John, "A Customizable approach to Full Lifecycle Variability Management," Science of Computer Programming, vol. 53, pp. 259-284, December 2004.
- [15] B. Williams and J. Carver, "Characterizing Software Architecture Changes: A Systematic Review," Information and Software Technology, vol. 52, pp. 31-51, January 2010.
- [16] A. Abran and J. W. Moore, "Guide to the Software Engineering Body of Knowledge - 2004 Version," P. Bourque and R. Dupuis, Eds. Los Alamitos, CA: IEEE Computer Society, 2004.
- [17] IEEE Computer Society Software Engineering Standards Committee, "IEEE Standard for a Software Quality Metrics Methodology." IEEE Std 1061-1998, 1998.
- [18] ISO/IEC, "Software engineering - Product quality - Part 1: Quality model." ISO/IEC 9126-1, 2001.
- [19] ISO/IEC, "Software engineering - Product quality - Part 2: External metrics," 2003, p. 86.
- [20] ISO/IEC, "Software engineering - Product quality - Part 3: Internal metrics," 2003, p. 62.
- [21] ISO/IEC, "Software engineering - Product quality - Part 4: Quality in use metrics," 2004, p. 59.

- [22] L. O'Brien, L. Bass, and P. Merson, "Quality Attributes and Service-Oriented Architectures," SEI CMU, Pittsburgh, PA, Technical Note CMU/SEI-2005-TN-014, September 2005.
- [23] A. Gehlert and A. Metzger, "Quality Reference Model for SBA," S-Cube 2009.
- [24] H. Zhang and M. A. Babar, "On Searching Relevant Studies in Software Engineering," Proc. Evaluation and Assessment in Software Engineering (EASE 10), BCS, 2010, pp. 1-10.
- [25] L. Chen, M. A. Babar, and N. Ali, "Variability Management in Software Product Lines: A Systematic Review," Proc. 13th International Software Product Line Conference (SPLC), Carnegie Mellon University, 2009, pp. 81-90.
- [26] P. Brereton, N. Gold, D. Budgen, K. Bennett, and N. Mehandjiev, "Service-based Systems: A Systematic Literature Review of Issues," Keele University, Staffordshire, Technical Report 2005.
- [27] A. Kontogogos and P. Avgeriou, "Towards Modelling Variability-intensive SOA Systems," University of Groningen, The Netherlands, Technical Report 2009.
- [28] W. Anderson, "What COTS and Software Reuse Teach Us about SOA," Proc. 6th International IEEE Conference on Commercial-off-the-Shelf (COTS)-Based Software Systems, IEEE Computer Society, 2007, pp. 141-149.
- [29] K. Kontogiannis, G. A. Lewis, D. B. Smith, and M. Litoiu, "The Landscape of Service-Oriented Systems: A Research Perspective," Proc. International Workshop on Systems Development in SOA Environments, IEEE Computer Society, 2007, pp. 1-6.
- [30] G. C. Gannod, J. E. Burge, and S. D. Urban, "Issues in the Design of Flexible and Dynamic Service-Oriented Systems," Proc. International Workshop on Systems Development in SOA
- [31] P. Brereton, B. Kitchenham, D. Budgen, M. Turner, and M. Khalil, "Lessons from applying the Systematic Literature Review process within the Software Engineering Domain," Journal of Systems and Software, vol. 80, pp. 571-583, April 2007.
- [32] Australian Research Council. (2010, June 14). Ranked Outlets. [Online]. Available: http://www.arc.gov.au/era/era_journal_list.htm.
- [33] M. S. Ali, M. A. Babar, L. Chen, and K.-J. Stol, "A Systematic Review of Comparative Evidence of Aspect-oriented Programming," Information and Software Technology, 2010.
- [34] T. Dyba and T. Dingsoyr, "Empirical Studies of Agile Software Development: A Systematic Review," Information and Software Technology, vol. 50, pp. 833-859, August 2008.
- [35] L. Chen, M. A. Babar, and C. Cawley, "A Status Report on the Evaluation of Variability Management Approaches," Proc. 13th International Conference on Evaluation and Assessment in Software Engineering (EASE), BCS, 2009, pp. 1-10.
- [36] C. Alves, G. Valenca, T. Sotero, and J. Mendes, "Requirements Engineering Process Improvement: A Knowledge Transfer Experience," Proc. 2008 ACM Symposium on Applied Computing, ACM, 2008, pp. 619-623.
- [37] M. Shaw, "Writing Good Software Engineering Research Papers," Proc. 25th International Conference on Software Engineering, IEEE Computer Society, 2003, pp. 726-736.
- [38] R. K. Yin, Case Study Research - Design and Methods. London, UK: Sage Publications, 2003.
- [39] C. Zannier, G. Melnik, and F. Maurer, "On the Success of Empirical Studies in the International Conference on Software Engineering," Proc. 28th International Conference on Software Engineering, ACM, 2006, pp. 341-350.
- [40] V. Basili, R. W. Selby, and D. H. Hutchens, "Experimentation in Software Engineering," IEEE Transactions on Software Engineering, vol. 12, pp. 733-743, 1986.
- [41] R. Glass, I. Vessey, and V. Ramesh, "Research in Software Engineering: An Analysis of the Literature," Information and Software Technology, vol. 44, pp. 491-506, 2002.
- [42] M. Zelkowitz and D. R. Wallace, "Experimental Models for Validating Technology," IEEE Computer, pp. 23-31, 1998.

- [43] B. Kitchenham and S. Charters, "Guidelines for Performing Systematic Literature Reviews in Software Engineering," Keele University, Technical Report 2007.
- [44] M. S. Ali, M. A. Babar, L. Chen, and K.-J. Stol, "A Systematic Review of Comparative Evidence of Aspect-oriented Programming," *Information and Software Technology*, 2010.
- [45] Hofmeister C, Kruchten P, Nord RL, et al. Generalizing a Model of Software Architecture Design from Five Industrial Approaches. 5th Working IEEE/IFIP Conference on Software Architecture (WICSA'05). 2005:77-88.
- [46] S. Cohen and R. Krut, "Managing Variation in Services in a Software Product Line Context," CMU SEI, Pittsburgh, PA, Technical Note CMU/SEI-2010-TN-007, 2010.
- [47] M. Staples and M. Niazi, "Experiences using systematic review guidelines," *Journal of Systems and Software*, vol. 80, pp. 1425-1437, September 2007.
- [48] J. Biolchini, P. Mian, A. Natali, and G. Travassos, "Systematic Review in Software Engineering," Programa de Engenharia de Sistemas e Computacao, Rio de Janeiro, Brazil, Technical Report RT - ES 679 / 05, 2005.
- [49] M. Riaz, M. Sulayman, N. Salleh, and E. Mendes, "Experiences Conducting Systematic Reviews from Novices' Perspective," *Proc. Evaluation and Assessment in Software Engineering (EASE 10)*, BCS, 2010, pp. 1-10.
- [50] B. Kitchenham, P. Brereton, D. Budgen, M. Turner, J. Bailey, and S. Linkman, "Systematic Literature Reviews in Software Engineering - A Systematic Literature Review," *Information and Software Technology*, vol. 51, pp. 7-15, 2009.
- [51] B. Kitchenham, R. Pretorius, D. Budgen, P. Brereton, M. Turner, M. Niazi, and S. Linkman, "Systematic Literature Reviews in Software Engineering - A Tertiary Study," *Information and Software Technology*, vol. 52, pp. 792-805, August 2010.
- [52] Mario R. Barbacci, Robert Ellison, Anthony J. Lattanze, Judith A. Stafford, Charles B. Weinstock, William G. Wood, "Quality Attribute Workshops (QAWs)", Third Edition, CMU/SEI-2003-TR-016, ESC-TR-2003-016

Appendix A- Detailed search strings

Electronic Source	Science Direct
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" OR "Service-level" OR "SLA" AND LIMIT-TO(smi, "5963,5651,5642", "European Journal of Operational Research,Journal of Systems and Software,Information and Software Technology") AND EXCLUDE(topics, "vehicle routing,markov chain,genetic algorithm,location problem,nash equilibrium") AND LIMIT-TO(smi, "5651", "Journal of Systems and Software") AND EXCLUDE(topics, "mobile agent,web application,sensor network,intrusion detection,node,iso,project management,real-time system,resource management,ware process") AND EXCLUDE(topics, "inter face,petri net,special issue,access control,distributed system,moving object,smart card,state machine,task,datum flow,resource allocation,sub system,ware engineering") AND EXCLUDE(topics, "business process,embedded system,knowledge grid,missing datum,mobile client,p2p network,signature scheme,tcp connection,test case,uml model,web site,quarc noc,reference architecture") AND LIMIT-TO(topics, "soft ware,product line,information system,quality attribute,design pattern,architecture design"

Electronic Source	Science Direct
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" OR "Service-level" OR "SLA" AND LIMIT-TO(smi, "5963,5651,5642", "European Journal of Operational Research,Journal of Systems and Software,Information and Software Technology") AND EXCLUDE(topics, "vehicle routing,markov chain,genetic algorithm,location problem,nash equilibrium") AND LIMIT-TO(smi, "5651", "Journal of Systems and Software") AND EXCLUDE(topics, "mobile agent,web application,sensor network,intrusion detection,node,iso,project management,real-time system,resource management,ware process") AND EXCLUDE(topics, "inter face,petri net,special issue,access control,distributed system,moving object,smart card,state machine,task,datum flow,resource allocation,sub system,ware engineering") AND EXCLUDE(topics, "business process,embedded system,knowledge grid,missing datum,mobile client,p2p network,signature scheme,tcp connection,test case,uml model,web site,quarc noc,reference architecture") AND LIMIT-TO(topics, "soft ware,product line,information system,quality attribute,design pattern,architecture design"

Electronic Source	Science Direct
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation

	<p>point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND EXCLUDE(smi, "5635,6234","Expert Systems with Applications,Computer Networks") AND EXCLUDE(smi, "5915,5979,6094,5951,6063,6187,5700,12890","Computer Law & Security Review,Computers in Human Behavior,Network Security,Telecommunications Policy,Environmental Modelling & Software,Computer Fraud & Security,Computers in Industry,Ad Hoc Networks") AND EXCLUDE(smi, "5006,17974,5004","Computers and Electronics in Agriculture,Journal of the American Medical Informatics Ass...,Computer Methods and Programs in Biomedicine") AND EXCLUDE(smi, "5066,5870,5630,5880,5628,5948,6610","International Journal of Medical Informatics,Computers & Security,Data & Knowledge Engineering,Computational Statistics & Data Analysis,Computer Standards & Interfaces,Information Processing & Management,Card Technology Today") AND EXCLUDE(smi, "5840,6848,7295,5652,5640,7329","Computers & Geosciences,Journal of Biomedical Informatics,Simulation Modelling Practice and Theory,Knowledge-Based Systems,Signal Processing: Image Communication,Electronic Commerce Research and Applications") AND EXCLUDE(smi, "5711,5673,5901,5644,5664,5706","International Journal of Electrical Power &...,Journal of Systems Architecture,Computers, Environment and Urban Systems,Interacting with Computers,Pattern Recognition,Engineering Applications of Artificial Intellig...") AND EXCLUDE(smi, "5660,5751","Neurocomputing,Microelectronics Reliability") AND EXCLUDE(smi, "6091,5666,6040,5668","Information Security Technical Report,Robotics and Autonomous Systems,Transportation Research Part C: Emerging Techno...,Signal Processing") AND EXCLUDE(topics, "service department,customer service,supply chain,sensor network,internet,inter face,markov chain,neural network,artificial intelligence,electronic note,semantic web") AND EXCLUDE(topics, "genetic algorithm,decision support,hoc network,atm network") AND EXCLUDE(smi, "5878","Decision Support Systems") AND EXCLUDE(topics, "mobile agent,wireless network") AND LIMIT-TO(smi, "5643","Information Sciences")</p>
--	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Science Direct
<p>Search String</p>	<p>"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND EXCLUDE(smi, "5635,6234","Expert Systems with Applications,Computer Networks") AND EXCLUDE(smi, "5915,5979,6094,5951,6063,6187,5700,12890","Computer Law & Security Review,Computers in Human Behavior,Network Security,Telecommunications Policy,Environmental Modelling & Software,Computer Fraud & Security,Computers in Industry,Ad Hoc Networks") AND EXCLUDE(smi, "5006,17974,5004","Computers and Electronics in Agriculture,Journal of the American Medical Informatics Ass...,Computer Methods and Programs in Biomedicine") AND EXCLUDE(smi, "5066,5870,5630,5880,5628,5948,6610","International Journal of Medical Informatics,Computers & Security,Data & Knowledge Engineering,Computational Statistics & Data Analysis,Computer Standards & Interfaces,Information Processing & Management,Card Technology Today") AND EXCLUDE(smi, "5840,6848,7295,5652,5640,7329","Computers & Geosciences,Journal of Biomedical Informatics,Simulation Modelling Practice and Theory,Knowledge-Based Systems,Signal Processing: Image Communication,Electronic Commerce Research and Applications") AND EXCLUDE(smi, "5711,5673,5901,5644,5664,5706","International Journal of Electrical Power &...,Journal of Systems Architecture,Computers, Environment and Urban Systems,Interacting with Computers,Pattern Recognition,Engineering Applications of Artificial Intellig...") AND EXCLUDE(smi, "5660,5751","Neurocomputing,Microelectronics Reliability") AND EXCLUDE(smi, "6091,5666,6040,5668","Information Security Technical Report,Robotics and Autonomous Systems,Transportation Research Part C: Emerging Techno...,Signal Processing") AND EXCLUDE(topics, "service department,customer service,supply chain,sensor network,internet,inter face,markov</p>

	chain,neural network,artificial intelligence,electronic note,semantic web") AND EXCLUDE(topics, "genetic algorithm,decision support,hoc network,atm network") AND EXCLUDE(smi, "5878","Decision Support Systems") AND EXCLUDE(topics, "mobile agent,wireless network") AND LIMIT-TO(smi, "5642","Information and Software Technology")
--	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Science Direct
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND EXCLUDE(smi, "5635,6234","Expert Systems with Applications,Computer Networks") AND EXCLUDE(smi, "5915,5979,6094,5951,6063,6187,5700,12890","Computer Law & Security Review,Computers in Human Behavior,Network Security,Telecommunications Policy,Environmental Modelling & Software,Computer Fraud & Security,Computers in Industry,Ad Hoc Networks") AND EXCLUDE(smi, "5006,17974,5004","Computers and Electronics in Agriculture,Journal of the American Medical Informatics Ass...,Computer Methods and Programs in Biomedicine") AND EXCLUDE(smi, "5066,5870,5630,5880,5628,5948,6610","International Journal of Medical Informatics,Computers & Security,Data & Knowledge Engineering,Computational Statistics & Data Analysis,Computer Standards & Interfaces,Information Processing & Management,Card Technology Today") AND EXCLUDE(smi, "5840,6848,7295,5652,5640,7329","Computers & Geosciences,Journal of Biomedical Informatics,Simulation Modelling Practice and Theory,Knowledge-Based Systems,Signal Processing: Image Communication,Electronic Commerce Research and Applications") AND EXCLUDE(smi, "5711,5673,5901,5644,5664,5706","International Journal of Electrical Power &...,Journal of Systems Architecture,Computers, Environment and Urban Systems,Interacting with Computers,Pattern Recognition,Engineering Applications of Artificial Intellig...") AND EXCLUDE(smi, "5660,5751","Neurocomputing,Microelectronics Reliability") AND EXCLUDE(smi, "6091,5666,6040,5668","Information Security Technical Report,Robotics and Autonomous Systems,Transportation Research Part C: Emerging Techno...,Signal Processing") AND EXCLUDE(topics, "service department,customer service,supply chain,sensor network,internet,inter face,markov chain,neural network,artificial intelligence,electronic note,semantic web") AND EXCLUDE(topics, "genetic algorithm,decision support,hoc network,atm network") AND EXCLUDE(smi, "5878","Decision Support Systems") AND EXCLUDE(topics, "mobile agent,wireless network") AND LIMIT-TO(smi, "6908","Journal of Parallel and Distributed Computing")

Electronic Source	Science Direct
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND EXCLUDE(smi, "5635,6234","Expert Systems with Applications,Computer

	<p>Networks") AND EXCLUDE(smi, "5915,5979,6094,5951,6063,6187,5700,12890","Computer Law & Security Review,Computers in Human Behavior,Network Security,Telecommunications Policy,Environmental Modelling & Software,Computer Fraud & Security,Computers in Industry,Ad Hoc Networks") AND EXCLUDE(smi, "5006,17974,5004","Computers and Electronics in Agriculture,Journal of the American Medical Informatics Ass...,Computer Methods and Programs in Biomedicine") AND EXCLUDE(smi, "5066,5870,5630,5880,5628,5948,6610","International Journal of Medical Informatics,Computers & Security,Data & Knowledge Engineering,Computational Statistics & Data Analysis,Computer Standards & Interfaces,Information Processing & Management,Card Technology Today") AND EXCLUDE(smi, "5840,6848,7295,5652,5640,7329","Computers & Geosciences,Journal of Biomedical Informatics,Simulation Modelling Practice and Theory,Knowledge-Based Systems,Signal Processing: Image Communication,Electronic Commerce Research and Applications") AND EXCLUDE(smi, "5711,5673,5901,5644,5664,5706","International Journal of Electrical Power &...,Journal of Systems Architecture,Computers, Environment and Urban Systems,Interacting with Computers,Pattern Recognition,Engineering Applications of Artificial Intellig...") AND EXCLUDE(smi, "5660,5751","Neurocomputing,Microelectronics Reliability") AND EXCLUDE(smi, "6091,5666,6040,5668","Information Security Technical Report,Robotics and Autonomous Systems,Transportation Research Part C: Emerging Techno...,Signal Processing") AND EXCLUDE(topics, "service department,customer service,supply chain,sensor network,internet,inter face,markov chain,neural network,artificial intelligence,electronic note,semantic web") AND EXCLUDE(topics, "genetic algorithm,decision support,hoc network,atm network") AND EXCLUDE(smi, "5878","Decision Support Systems") AND EXCLUDE(topics, "mobile agent,wireless network") AND LIMIT-TO(smi, "6646","Applied Soft Computing")</p>
--	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Science Direct
Search String	<p>and "service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND EXCLUDE(smi, "5635,6234","Expert Systems with Applications,Computer Networks") AND EXCLUDE(smi, "5915,5979,6094,5951,6063,6187,5700,12890","Computer Law & Security Review,Computers in Human Behavior,Network Security,Telecommunications Policy,Environmental Modelling & Software,Computer Fraud & Security,Computers in Industry,Ad Hoc Networks") AND EXCLUDE(smi, "5006,17974,5004","Computers and Electronics in Agriculture,Journal of the American Medical Informatics Ass...,Computer Methods and Programs in Biomedicine") AND EXCLUDE(smi, "5066,5870,5630,5880,5628,5948,6610","International Journal of Medical Informatics,Computers & Security,Data & Knowledge Engineering,Computational Statistics & Data Analysis,Computer Standards & Interfaces,Information Processing & Management,Card Technology Today") AND EXCLUDE(smi, "5840,6848,7295,5652,5640,7329","Computers & Geosciences,Journal of Biomedical Informatics,Simulation Modelling Practice and Theory,Knowledge-Based Systems,Signal Processing: Image Communication,Electronic Commerce Research and Applications") AND EXCLUDE(smi, "5711,5673,5901,5644,5664,5706","International Journal of Electrical Power &...,Journal of Systems Architecture,Computers, Environment and Urban Systems,Interacting with Computers,Pattern Recognition,Engineering Applications of Artificial Intellig...") AND EXCLUDE(smi, "5660,5751","Neurocomputing,Microelectronics Reliability") AND EXCLUDE(smi, "6091,5666,6040,5668","Information Security Technical Report,Robotics and Autonomous Systems,Transportation Research Part C: Emerging Techno...,Signal Processing") AND EXCLUDE(topics, "service department,customer service,supply chain,sensor network,internet,inter face,markov chain,neural network,artificial intelligence,electronic note,semantic web") AND EXCLUDE(topics, "genetic algorithm,decision support,hoc network,atm network") AND EXCLUDE(smi, "5878","Decision Support Systems") AND EXCLUDE(topics, "mobile agent,wireless network") AND LIMIT-TO(smi, "5680","Advances in Engineering Software")</p>
Electronic Source	Scopus (2000/01)

Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2001) OR LIMIT-TO(PUBYEAR, 2000)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))
----------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Scopus (2002)
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2002)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))

Electronic Source	Scopus (2003)
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a

	<p>service" OR "SaS" OR "SaaS" AND"change" OR "changes" OR "modification" OR "modifications" OR "m odify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR"variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR"Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p"))AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA,"MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2003)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))</p>
--	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Scopus (2004)
Search String	<p>"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND"change" OR "changes" OR "modification" OR "modifications" OR "m odify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR"variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR"Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p"))AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA,"MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2004)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))</p>

Electronic Source	Scopus (2005)
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2005)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))

Electronic Source	Scopus (2006)
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2006)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))

Electronic Source	Scopus (2007)
--------------------------	---------------

Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2007)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))
----------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Scopus (2008)
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND "change" OR "changes" OR "modification" OR "modifications" OR "modify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR "variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR "Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2008)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))

Electronic Source	Scopus (2009)
Search String	"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service

	<p>based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND"change" OR "changes" OR "modification" OR "modifications" OR "m odify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR"variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR"Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p"))AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA,"MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2009)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))</p>
--	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	Scopus (2010-2011)
<p>Search String</p>	<p>"service" OR "services" OR "service-oriented" OR "service oriented" OR "service-based" OR "service based" OR "SOA" OR "software as service" OR "software as a service" OR "SaS" OR "SaaS" AND"change" OR "changes" OR "modification" OR "modifications" OR "m odify" OR "flexibility" OR "flexibilities" OR "product line" OR "product lines" OR "product family" OR "product families" OR "variability" OR"variabilities" OR "variant" OR "variants" OR "variation" OR "variations" OR "variation point" OR "variation points" OR "adaptive" OR "adapt" OR "adaptation" OR "aware" AND "aspect" OR "aspects" OR "cross-cutting" OR "non-functional" OR "quality" OR "qualities" OR "quality attribute" OR "quality attributes" OR "quality factor" OR "quality factors" OR "System Quality" OR "System Qualities" OR "Performance" OR"Security" OR "Reliability" OR "Availability" OR "QoS" OR "Quality of Service" OR "Service level" AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p"))AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p")) AND (LIMIT-TO(SUBJAREA, "ENGI") OR LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA,"MULT")) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(PUBYEAR, 2011) OR LIMIT-TO(PUBYEAR,2010)) AND (LIMIT-TO(EXACTKEYWORD, "Quality of service")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "p") OR LIMIT-TO(SRCTYPE, "j"))</p>

Electronic Source	ACM (2000-2005)
Search String	<p>((("service" or "services" or "SOA" or "SaS" or "SaaS") and ("change" or "modification" or "modify" or "flexibility" or "flexibilities" or "product line" or "product family" or "product families" or "variability" or "variabilities" or "variant" or "variation" or "variations" or "adaptive" or "adapt" or "aware") and ("aspect" or "cross-cutting" or "non-functional" or "quality" or "qualities" or "quality attributes" or "quality factor" or "Performance" or "Security" or "Reliability" or "Availability" or "QoS") and (PublishedAs:journal OR PublishedAs:proceeding) and (FtFlag:yes))))</p> <p>Included:</p> <p>ACM SIGPLAN Notices <i>or</i> ACM SIGCOMM Computer Communication Review <i>or</i> ACM SIGCSE Bulletin <i>or</i> ACM SIGMETRICS Performance Evaluation Review <i>or</i> Proceedings of the SIGCHI conference on Human factors in computing systems <i>or</i> Proceedings of the 2008 ACM symposium on Applied computing <i>or</i> Proceedings of the 2009 ACM symposium on Applied Computing <i>or</i> Proceedings of the 2005 ACM symposium on Applied computing <i>or</i> Proceedings of the 27th international conference on Human factors in computing systems <i>or</i> Proceedings of the 2nd International Conference on Interaction Sciences: Information Technology, Culture and Human <i>or</i> Proceeding of the 17th international conference on World Wide Web <i>or</i> Proceedings of the 11th International Conference on Information Integration and Web-based Applications & Services <i>or</i> Proceedings of the International Conference on Mobile Technology, Applications, and Systems <i>or</i> Proceedings of the International Conference on Management of Emergent Digital EcoSystems <i>or</i> Proceedings of the 2011 iConference <i>or</i> Proceedings of the 1st international conference on Theory and practice of electronic governance <i>or</i> Proceedings of the 6th International Conference on Advances in Mobile Computing and Multimedia <i>or</i> Computer Supported Cooperative Work <i>or</i> Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops <i>or</i> Proceedings of the 14th international conference on Software engineering and knowledge engineering <i>or</i> Proceedings of the 2008 ACM SIGMOD international conference on Management of data <i>or</i> Proceedings of the 1st international conference on MOBILE Wireless MiddleWARE, Operating Systems, and Applications <i>or</i> Real-Time Systems <i>or</i> Proceedings of the 2009 Seventh Annual Communication Networks and Services Research Conference <i>or</i> Proceedings of the ACM SIGCOMM 2008 conference on Data communication <i>or</i> Proceedings of the Fourth ACM International Conference on Distributed Event-Based Systems <i>or</i> Proceedings of the 11th workshop on ACM SIGOPS European workshop <i>or</i> Proceedings of the ACM SIGMETRICS international conference on Measurement and modeling of computer systems <i>or</i> Proceedings of the ACM international conference on Object oriented programming systems languages and applications <i>or</i> Proceedings of the 2007 international conference on Computer systems and technologies <i>or</i> Proceedings of the 12th ACM conference on Computer and communications security <i>or</i> Proceedings of the 12th ACM symposium on Access control models and technologies <i>or</i> Proceedings of the 8th Workshop on Performance Metrics for Intelligent Systems <i>or</i> Proceedings of the 21st International Workshop on Principles of Advanced and Distributed Simulation <i>or</i> FIP/ACM International Conference on Distributed systems platforms <i>or</i> Proceedings of the 2007 symposium on Component and framework technology in high-performance and scientific computing <i>or</i> Proceedings of the 2009 International Conference on Advanced Information Networking and Applications Workshops <i>or</i> Proceedings of the 4th ACM international workshop on Experimental evaluation and characterization <i>or</i> Proceedings of the 2005 workshop on Secure web services <i>or</i> Proceedings of the 2009 Congress on Services - I <i>or</i> Proceedings of the 2009 ICSE Workshop on Software Engineering in Health Care <i>or</i> Proceedings of the 2006 workshop on New security paradigms <i>or</i> Proceedings of the 2008 Second IEEE International Conference on Self-Adaptive and Self-Organizing Systems <i>or</i> Proceedings of the 16th ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications <i>or</i> Proceedings of the 2009 International Conference on Computational Science and Engineering - Volume 02 <i>or</i> Proceedings of the 2008</p>

	IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology - Volume 01 <i>or</i> Proceedings of the 2010 18th Euromicro Conference on Parallel, Distributed and Network-based Processing <i>or</i> Proceedings of the 2008 IEEE International Conference on Software Testing Verification and Validation Workshop
--	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	ACM (2006-2008)
Search String	<p>((("service" or "services" or "SOA" or "SaS" or "SaaS") and ("change" or "modification" or "modify" or "flexibility" or "flexibilities" or "product line" or "product family" or "product families" or "variability" or "variabilities" or "variant" or "variation" or "variations" or "adaptive" or "adapt" or "aware") and ("aspect" or "cross-cutting" or "non-functional" or "quality" or "qualities" or "quality attributes" or "quality factor" or "Performance" or "Security" or "Reliability" or "Availability" or "QoS") and (PublishedAs:journal OR PublishedAs:proceeding) and (FtFlag:yes))))</p> <p>Include: ACM SIGPLAN Notices <i>or</i> ACM SIGCOMM Computer Communication Review <i>or</i> ACM SIGCSE Bulletin <i>or</i> ACM SIGMETRICS Performance Evaluation Review <i>or</i> Proceedings of the SIGCHI conference on Human factors in computing systems <i>or</i> Proceedings of the 2008 ACM symposium on Applied computing <i>or</i> Proceedings of the 2009 ACM symposium on Applied Computing <i>or</i> Proceedings of the 2005 ACM symposium on Applied computing <i>or</i> Proceedings of the 27th international conference on Human factors in computing systems <i>or</i> Proceedings of the 2nd International Conference on Interaction Sciences: Information Technology, Culture and Human <i>or</i> Proceeding of the 17th international conference on World Wide Web <i>or</i> Proceedings of the 11th International Conference on Information Integration and Web-based Applications & Services <i>or</i> Proceedings of the International Conference on Mobile Technology, Applications, and Systems <i>or</i> Proceedings of the International Conference on Management of Emergent Digital EcoSystems <i>or</i> Proceedings of the 2011 iConference <i>or</i> Proceedings of the 1st international conference on Theory and practice of electronic governance <i>or</i> Proceedings of the 6th International Conference on Advances in Mobile Computing and Multimedia <i>or</i> Computer Supported Cooperative Work <i>or</i> Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops <i>or</i> Proceedings of the 14th international conference on Software engineering and knowledge engineering <i>or</i> Proceedings of the 2008 ACM SIGMOD international conference on Management of data <i>or</i> Proceedings of the 1st international conference on MOBILE Wireless MiddleWARE, Operating Systems, and Applications <i>or</i> Real-Time Systems <i>or</i> Proceedings of the 2009 Seventh Annual Communication Networks and Services Research Conference <i>or</i> Proceedings of the ACM SIGCOMM 2008 conference on Data communication <i>or</i> Proceedings of the Fourth ACM International Conference on Distributed Event-Based Systems <i>or</i> Proceedings of the 11th workshop on ACM SIGOPS European workshop <i>or</i> Proceedings of the ACM SIGMETRICS international conference on Measurement and modeling of computer systems <i>or</i> Proceedings of the ACM international conference on Object oriented programming systems languages and applications <i>or</i> Proceedings of the 2007 international conference on Computer systems and technologies <i>or</i> Proceedings of the 12th ACM conference on Computer and communications security <i>or</i> Proceedings of the 12th ACM symposium on Access control models and technologies <i>or</i> Proceedings of the 8th Workshop on Performance Metrics for Intelligent Systems <i>or</i> Proceedings of the 21st International Workshop on Principles of Advanced and Distributed Simulation <i>or</i> FIP/ACM International Conference on Distributed systems platforms <i>or</i> Proceedings of the 2007 symposium on Component and framework technology in high-performance and scientific computing <i>or</i> Proceedings of the 2009 International Conference on Advanced Information Networking and Applications Workshops <i>or</i> Proceedings of the 4th ACM international workshop on Experimental evaluation and characterization <i>or</i> Proceedings of the 2005</p>

	workshop on Secure web services <i>or</i> Proceedings of the 2009 Congress on Services - I <i>or</i> Proceedings of the 2009 ICSE Workshop on Software Engineering in Health Care <i>or</i> Proceedings of the 2006 workshop on New security paradigms <i>or</i> Proceedings of the 2008 Second IEEE International Conference on Self-Adaptive and Self-Organizing Systems <i>or</i> Proceedings of the 16th ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications <i>or</i> Proceedings of the 2009 International Conference on Computational Science and Engineering - Volume 02 <i>or</i> Proceedings of the 2008 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology - Volume 01 <i>or</i> Proceedings of the 2010 18th Euromicro Conference on Parallel, Distributed and Network-based Processing <i>or</i> Proceedings of the 2008 IEEE International Conference on Software Testing Verification and Validation Workshop
--	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Electronic Source	ACM (2009-2011)
Search String	<p>((("service" or "services" or "SOA" or "SaS" or "SaaS") and ("change" or "modification" or "modify" or "flexibility" or "flexibilities" or "product line" or "product family" or "product families" or "variability" or "variabilities" or "variant" or "variation" or "variations" or "adaptive" or "adapt" or "aware") and ("aspect" or "cross-cutting" or "non-functional" or "quality" or "qualities" or "quality attributes" or "quality factor" or "Performance" or "Security" or "Reliability" or "Availability" or "QoS") and (PublishedAs:journal OR PublishedAs:proceeding) and (FtFlag:yes))))</p> <p>Included:</p> <p>ACM SIGCOMM Computer Communication Review <i>or</i> ACM SIGMETRICS Performance Evaluation Review <i>or</i> Proceedings of the 2008 ACM symposium on Applied computing <i>or</i> Proceedings of the 2009 ACM symposium on Applied Computing <i>or</i> Proceedings of the 2005 ACM symposium on Applied computing <i>or</i> Proceedings of the 11th International Conference on Information Integration and Web-based Applications & Services <i>or</i> Proceedings of the International Conference on Mobile Technology, Applications, and Systems <i>or</i> Proceedings of the 2011 iConference <i>or</i> Proceedings of the 1st international conference on Theory and practice of electronic governance <i>or</i> Computer Supported Cooperative Work <i>or</i> Proceedings of the 14th international conference on Software engineering and knowledge engineering <i>or</i> Real-Time Systems <i>or</i> Proceedings of the ACM SIGCOMM 2008 conference on Data communication <i>or</i> Proceedings of the Fourth ACM International Conference on Distributed Event-Based Systems <i>or</i> Proceedings of the 11th workshop on ACM SIGOPS European workshop <i>or</i> Proceedings of the ACM SIGMETRICS international conference on Measurement and modeling of computer systems <i>or</i> Proceedings of the 2007 international conference on Computer systems and technologies <i>or</i> Proceedings of the 12th ACM symposium on Access control models and technologies <i>or</i> Proceedings of the 21st International Workshop on Principles of Advanced and Distributed Simulation <i>or</i> IFIP/ACM International Conference on Distributed systems platforms <i>or</i> Proceedings of the 2007 symposium on Component and framework technology in high-performance and scientific computing <i>or</i> Proceedings of the 4th ACM international workshop on Experimental evaluation and characterization <i>or</i> Proceedings of the 2009 Congress on Services - I <i>or</i> Proceedings of the 2009 ICSE Workshop on Software Engineering in Health Care <i>or</i> Proceedings of the 2008 Second IEEE International Conference on Self-Adaptive and Self-Organizing Systems <i>or</i> Proceedings of the 2009 International Conference on Computational Science and Engineering - Volume 02 <i>or</i> Proceedings of the 2008 IEEE International Conference on Software Testing Verification and Validation Workshop</p>

Electronic Source	SpringerLink
Search String	((service or SOA) and (quality or qualities orQoS) and (variability or adapt or change)) With filters: Computer Science year Software Engineering

Electronic Source	SpringerLink
Search String	((service or SOA) and (quality or qualities orQoS) and (variability or adapt or change)) With filters: Lecture Notes in Business Information Processing year

Electronic Source	Web of Science
Search String	Title=((service OR service-oriented OR service oriented OR service-based OR service based OR SOA OR SaS OR SaaS)) AND Title=((change OR modification OR modifications OR modify OR flexibility OR flexibilities OR product line OR product lines OR product family OR product families OR variability OR variabilities OR variant OR variants OR variation OR variations OR variation point OR variation points OR adaptive OR adapt OR adaptation OR aware)) AND Title=((aspect OR cross-cutting OR non-functional OR quality OR qualities OR quality attribute OR quality factor OR System Qualities OR Performance OR Security OR Reliability OR Availability OR QoS OR Quality of Service OR Service level)) Refined by: Subject Areas=(COMPUTER SCIENCE, CYBERNETICS OR COMPUTER SCIENCE, THEORY & METHODS OR COMPUTER SCIENCE, INFORMATION SYSTEMS OR COMPUTER SCIENCE, SOFTWARE ENGINEERING) Timespan=2000-2011. Databases=SCI-EXPANDED.

Electronic Source	IEEE Xplore
Search String	"service" or "services" or "SOA" or "SaS" or "SaaS" and "change" or "modification" or "modify" or "flexibility" or "flexibilities" or "product line" or "product family" or "product families" or "variability" or "variabilities" or "variant" or "variation" or "variations" or "adaptive" or "adapt" or "aware" and "aspect" or "cross-cutting" or "non-functional" or "quality" or "qualities" or "quality attributes" or "quality factor" or "Performance" or "Security" or "Reliability" or "Availability" or "QoS"

Appendix B- Results of manual search for quasi-gold standard

	2005	2006	2007	2008	2009	2010	2011	Number of papers considered	Number of relevant papers per
IEEE Transactions on Services Computing				16	25	29	6	76	0
Journal of Service Oriented Computing and Applications			18	15	19	20		72	2
International Conference on Service Oriented Computing	54	61	59	68	54	80		376	1
International Conference on Services Computing	102	107	131	150	76	90		656	5
International Conference on Web Services	25	137	198	139	143	116		758	3
ServiceWave Conference				28	54	39		121	7
Number of papers considered per year	181	305	406	416	371	374	6	2059	N/A
Number of relevant papers	1	0	4	4	1	8		N/A	18

Appendix C – Data extraction table

List of studies, including brief methods' descriptions, detailed runtime QAs and runtime QAs.

Study Identifier	Authors(s)	Method proposed	Runtime QAs	Design time QAs
S1	Nallur, V-Bahsoon, R-Yao, X	Each web service first specifies its QoS priorities then negotiates with other web services to find the best provider.	Performance, availability, reliability	Cost
S2	Narendra, N.C., Ponnalagu, Karthikeyan, Gomadam, Karthik, Sheth, Amit P.	Modeling variations in services in order to develop robust service composition and decrease the impact of variations	No specific QA	No specific QA
S3	Kim, YDoh, K.-G.	An approach for the dynamic composition of Web services with quality of services (QoS) attributes. They adopt a concept of mediator to select credible services for service requestors.	Availability, Reliability, Response time (performance)	Execution costs
S4	Jiang Chang-hai, Hu H A I, Cai Kai-yuan	A three-layer architecture for developing and deploying ASBS is presented to satisfy multiple QoS requirements in an open dynamic environment	Performance	None
S5	GMACH, KROMPASS, SCHOLZ, WIMMER, and KEMPER	Adaptive service management including three levels: 1. Static resource management optimizes the allocation of services to computing resources. 2. Dynamic resource management using a fuzzy logic based controller to remedy exceptional situations at runtime. 3. Adaptive control of service level agreements.	Performance, availability	None
S6	Rosenberg, F-Leitner, P -	A semi-automated "Composition as a Service" (CAAS) approach combined with a domain-specific language.	Availability, Reliable Messaging,	Price

	Michlmayr, A - Celikovic, P - Dustdar, S	The approach facilitates rapid development and provisioning of composite services by specifying what to compose in a constraint-hierarchy based way using VCL.	Throughput(response time, performance)	
S7	Sui, Yulei - Zhou, Xingshe - Yang, Gang	A dependable service-oriented middleware (DSM) is introduced which provides a framework with the functionalities of QoS monitoring, configuration and runtime management to fulfill user's QoS request. The approach is to decompose the QoS requirement for the composite service into separate ones for the atoms, and to deliver expected QoS for each atomic service with adaptive service scheduling mechanisms.	Availability, Response time, Reliability	Price
S8	Briones, J F - De Miguel, M A - Alonso, A - Silva, J P	Reuse of existing modeling languages and tools to create new ones to tackle the problem of quality of service adaptability and composition. Also evaluating architectural models to predict system's QoS behavior before it is implemented	No specific QA	No specific QA
S9	Wan, C - Wang, H	An uncertainty-aware QoS match-making model which describes the uncertainty QoS attributes under different conditions.	Response time (performance)	No specific QA
S10	Valeria Cardellini, Stefano Iannucci	A service broker that supports the QoS-driven runtime adaptation of SOA applications is presented.	Response time, availability	No specific QA
S11	Kanchana Rajaram, ChitraBabu	A framework for dynamic composition of Web services using templates in SOA. The key feature of this approach is its ability to react to exceptions such as service failures that may occur at runtime	No specific QA	No specific QA
S12	T. Rajendran, P. Balasubramanie	An agent-based architecture for web service discovery. The goal of the agent is to support web service discovery with QoS registration, verification, certification, and confirmation.	Response time, Throughput, availability	Cost
S13	Liu, B, Shi, Y, Wang, H	This paper proposes an algorithm of QoS oriented web service composition and optimization based on the initial business process structure made by the users to meet their QoS requirements.	Response time, Throughput	Cost
S14	Jun-Zhou Luo · Jing-Ya Zhou · Zhi- AngWu	An adaptive algorithm for QoS-aware service composition (AQSC) is proposed. In AQSC this problem is modeled as the Multi-Constrained Optimal Path selection problem (MCOP) and a heuristic approach for service selection is used, then backup services set is introduced as an adaptive mechanism when some candidate services fail or withdraw.	Throughput (performance)	Cost
S15	Zheng, Zibin - Lyu, Michael R.	This paper proposes a QoS-aware middleware for fault tolerant Web services. By having this middleware, service-oriented applications can dynamically adjust their optimal fault tolerance strategy to achieve good service reliability as well as good overall performance.	Reliability (Fault tolerance : Network- related faults and/or Logic-related faults)	No specific QA
S16	Diego Zuquim Guimarães Garcia, Maria Beatriz Felgar de Toledo	In this paper, the basic Web service architecture was extended to support QoS management. The method proposes a UDDI extension to include QoS attributes, the use of WS-Policy to specify QoS policies, the use of tModels to define QoS- related concepts, and QoS updating to reflect actual service attributes.	response time, throughput, availability, reliability	No specific QA
S17	Dunlu Peng, Qingkui Chen	A framework to collect the indices of service quality, both runtime and non-runtime indices, is provided. A fuzzy partial-ordering approach, which takes both quality indices and their uncertainty into consideration, is proposed to evaluate web services.	Availability, mean response time, and performance	Price

S18	Cardellini, V- Casalicchio, E- Grassi, V-Lo Presti, F-Mirandola, R	A methodology and a prototype tool are provided to achieve the self-adaptation of a SOA system to fulfill non-functional QoS requirements. The methodology is based on the formulation and solution of a linear programming problem, which is derived from a behavioral model of the system updated at runtime by a monitoring activity.	Reliability, performance	No specific QA
S19	Valeria Cardellini, Emiliano Casalicchio, Vincenzo Grassi, Francesco Lo Presti	A broker architecture is offered which supports multiple QoS classes, and a service selection scheme is provided which optimizes the end-to-end aggregated QoS of all incoming flows of requests by means of a simple linear programming problem.	Availability, Response time	Cost
S20	Alan Colman, Linh Duy Pham, Jun Han, Jean-Guy Schneider	Adaptive application-specific middleware composites are introduced which are adaptive runtime role structures allowing services to be composed and autonomously reconfigured.	performance	No specific QA
S21	Golshan, Farnoush - Barforoush, Ahmad Abdollahzade	A method is proposed for tracing quality attributes in service oriented architecture based on Graph Transformation System (GTS).	Security, performance	No specific QA
S22	Mu Li, Ting Deng, Hailong Sun, Huipeng Guo, Xudong Liu	A global optimization selection based on prediction mechanism for QoS values of local services is proposed. The GOS has two parts. First, local service selection algorithm can be used to predict the change of service quality information. Second, GOS aims to find solution satisfied user QoS's constraints.	Availability, response time	Price
S23	Yau, S S - Ye, N - Sarjoughian, H - Huang, D	A performance-model- oriented approach to develop ASBS is presented. The approach consists performance models for of the establishment of SBS, the development of QoS monitoring and adaptation (M/A) modules, and the validation of ASBS design.	timeliness, throughput, accuracy and security	No specific QA
S24	Smit, M - Nisbet, A - Stroulia, E - Iszlai, G- Edgar, A	The method includes generating a web service simulator that runs on a simulation engine. This simulator will be run automatically under various configurations to generate a knowledge base containing performance profiles. The knowledge base can be used to make configuration and decisions at deployment time and run- time.	Performance	Cost
S25	Gang YE, Chanle WU, Jun YUE, Shi CHENG -	A scalable QoS-aware model for Web Services discovery including a QoS Broker (including QoS Database, Publish, Lookup, Monitor and Valuate module) is proposed.	Response time, availability	Cost
S26	Bin Xu, Yixin Yan	This paper proposes an algorithm which uses dynamic programming to solve the QoS based service composition problem. The hypothesis is that QoS of SOS can be quantitatively calculated according to the included services and their relationships.	Response time, throughput	
S27	M Agni Catur Bhakti, Azween B. Abdullah	The idea presented in this paper is to adapt autonomic computing paradigm into SOA in order to achieve a more adaptive and robust SOA.	No specific QA	No specific QA
S28	Nastaran Jafarpour, Mohammad Reza Khayyambashi	The problem of QoS-aware selection of web service composition is modeled as an optimization problem, and a variation of Harmony Search algorithm is used to find a near-optimal composition which can satisfy local and global user's constraints on quality attributes	Response time, availability, reliability	Cost
S29	Kyriakos Kritikos and Dimitris Plexousakis	A road map for extending current WS standard technologies for realizing semantic, functional, and QoS-based WSDi is presented. In addition, a proposal	Availability, reliability, performance	Cost

		of how to produce a semantically enhanced and stand-alone QoS broker that could be used in a complementary way to current functional WS registries was given.		
S30	Hatvani, L- Jansen, A- Seceleanu, C- Pettersson, P	A tool for performing trade-off analysis of Quality-of-Service attributes for multiple design alternatives of SOS.	Performance, reliability	Cost
S31	Wei Zhang, Carl K. Chang, Taiming Feng, Hsin-yi Jiang	A new version of the Ant Colony Optimization algorithm is presented, and then a novel QoS based dynamic service composition technique based on the new ACO is provided.	Availability, Response time, Reliability	Cost
S32	Yau, S S- Ye, N- Sarjoughian, H S- Huang, D- Roontiva, A - Baydogan, M - Muqsith, M A	A methodology for constructing Activity-State-QoS models is presented, and then it is described how QoS monitoring modules in adaptive service-based software systems can be developed based on the ASQ models methodology.	Performance (Throughput)	No specific QA
S33	Loyall, Joseph P- Gillen, Matthew- Paulos, Aaron- Edmondson, James-Varshneya, Pooja-Schmidt,- Douglas C-Bunch, Larry-Carvalho, Marco-Martignoni, Andrew	This paper presents a policy-driven approach for managing QoS in SOA systems. It describes key capabilities needed in SOA middleware to make it suitable to support applications and systems that require predictable QoS, including (1) task management, (2) bandwidth management, (3) aggregation of competing resource demands, and (4) QoS policy-driven prioritization and scheduling strategies.	Performance, reliability(message passing)	No specific QA
S34	Litoiu, M- Mihaescu, M- Solomon, B- Ionescu, D	A reference robust control loop for maintaining the performance of a web service within prescribed limits is presented. The focus is on the characteristics which define the performance behavior of the web service and on the abstract models which can be used to describe it.	Performance	No specific QA
S35	GuijunWang Alice Chen ChangzhouWang Casey Fung Stephen Uczekaj	A general integrated QoS management architecture for the publish/subscribe style of enterprise service oriented architecture, a flexible and extensible XML-based QoS language, innovative resource models, and a policy-based resource management solution are presented.	Performance, reliability, security	No specific QA
S36	Ponnalagu, Karthikeyan - Krishnamurthy, Jayatheerthan R.	By using aspect-oriented programming an adaptive architecture for web services composition and execution is provided.	Security	No specific QA
S37	Liang-Jie Zhang, Ali Arsanjani, Abdul Allam, Dingding Lu, Yi-Min Chee	A framework for performing variation-oriented analysis in SOA solution design is proposed. Two types of change-oriented analysis patterns, variation-oriented analysis (VOA) and event-driven change analysis (EDCA), are presented to create a resilient design that is adaptive to changes.	No specific QA	Cost
S38	Srnaivas Padmanabbuni, Bijoy Majumdar, Mohit Chawla, Ujval Mysore	A constraint satisfaction based framework to model non-functional requirements and a logical architecture for constraint based adaptive web services are presented.	Availability (different definition from ours definition)	Cost
S39	N. Yasemin Topaloglu and Rafael Capilla	Architectural and pattern approaches are used to describe how Web services based systems can be designed including the notion of variability. In this way, the design of Web information systems can be	No specific QA	No specific QA

		improved with a good description of the variation points that introduce flexibility in the design process		
S40	Nanjangud C. Narendra, Karthikeyan Ponnalagu	A Variability Model for SOA-based solutions, through which variations in a service can be modeled and maintained, is proposed. The Variability Model clarifies the extent to which an existing service can be modified to suit a business process requirement. Also a rigorous definition of a “legal” service variant, and an algorithm to determine whether a service variant is legal is presented.	No specific QA	Cost
S41	Alessandro Bellucci, Valeria Cardellini, Valerio Di Valerio, and Stefano Iannucci	Design and architecture of MOSES (MODEL-based SELF-adaptation of SOA systems), a runtime adaptation framework for a SOA system is presented. MOSES’s goal is to drive the adaptation of the composite services it manages to fulfill the SLAs negotiated with its users	Availability	No specific QA
S42	Gerardo Canfora, Massimiliano Di Penta, Raffaele Esposito, Maria Luisa Villani	A QoS-aware binding approach based on Genetic Algorithms is presented. The approach includes a feature for early run-time re-binding when the actual QoS deviates from initial estimates or a service is not available. The binding and re-binding framework determines the bindings by solving, through GAs, a constrained optimization problem.	Response time (performance)	Price
S43	Sonia Ben Mokhtara, Davy Preuveneers, Nikolaos Georgantas, Vale Yolande Berbers	A solution for efficient, semantic, context- and QoS-aware service discovery, which can flexibly be deployed on top of existing Service Discovery Protocols is presented.	Security, Performance, Reliability	Cost
S44	Bleul, S, Zapf, M, Geihs, K	A concept of automatic service brokering as a model for automatic service discovery, replacement, and integration is presented. The model uses semantic information to describe services, service brokering requests and discovery results.	availability, Performance	No specific QA
S45	Pedro Furtado, Celso Santos	The design of a Contract-Broker architecture for implementing Quality-of-Service features and Self-properties is presented. The C-Broker is a middleware for delivering Quality- of-Service to applications. It can be integrated into an application or be deployed as a server daemon providing control to multiple applications	Performance	No specific QA
S46	Xiao-Ling Wang, Sheng Huang, Ao-Ying Zhou	The presented approach is based on a succinct binary tree data structure, and a system for composite service, and a heuristic based search method is proposed to retrieve top K composite services.	No specific QA	No specific QA

Appendix D - Papers included in the review

Authors(s)	Year	Title	Source
Nallur, V-Bahsoon, R-Yao, X	2009	Self-optimizing architecture for ensuring quality attributes in the cloud	2009 Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture, WICSA/ECSA 2009

Narendra, N.C., Ponnalagu, Karthikeyan, Gomadam, Karthik, Sheth, Amit P.	2007	Variation Oriented Service Composition and Adaptation (VOSCA): A Work in Progress	IEEE International Conference on Services Computing SCC 2007 (2007)
Kim, YDoh, K.-G.	2007	A trust type based model for managing QoS in Web services composition	2007 International Conference on Convergence Information Technology, ICCIT 2007
Jiang Chang-hai, Hu H A I, Cai Kai-yuan	2009	AN INTELLIGENT CONTROL ARCHITECTURE FOR ADAPTIVE SERVICE-BASED SOFTWARE SYSTEMS	International Journal of Software Engineering and Knowledge Engineering
GMACH, KROMPASS, SCHOLZ, WIMMER, and KEMPER	2008	Adaptive Quality of Service Management for Enterprise Services	ACM Transactions on the Web
Rosenberg, F- Leitner, P - Michlmayr, A - Celikovic, P - Dustdar, S	2009	Towards Composition as a Service – A Quality of Service Driven Approach	Data Engineering, 2009. ICDE '09. IEEE 25th International Conference on
Sui, Yulei - Zhou, Xingshe - Yang, Gang	2009	QoS Decomposition for Dependable Service-Oriented Middleware	2009 ISECS International Colloquium on Computing, Communication, Control, and Management
Briones, J F - De Miguel, M A - Alonso, A - Silva, J P	2009	Quality of Service Composition and Adaptability of Software Architectures	Proceedings of the 2009 IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing, ISORC 2009
Wan, C - Wang, H	2007	Uncertainty-aware QoS Description and Selection Model for Web Services	Proceedings - 2007 IEEE International Conference on Services Computing, SCC 2007
Valeria Cardellini, Stefano Iannucci	2010	Designing a broker for QoS-driven runtime adaptation of SOA applications	ICWS 2010 - 2010 IEEE 8th International Conference on Web Services
Kanchana Rajaram, ChitraBabu	2010	Template based SOA framework for dynamic and adaptive composition of Web Services	Networking and Information Technology (ICNIT), 2010 International Conference on
T. Rajendran, P. Balasubramanie	2010	An OptimalAgent-Based Architecture for Dynamic Web Service Discovery with QoS	2010 Second International conference on Computing, Communication and Networking Technologies
Liu, B, Shi, Y, Wang, H	2009	QoS Oriented Web Service Composition and Optimization in SOA	2009 Joint Conferences on Pervasive Computing, JCPC 2009
Jun-Zhou Luo · Jing-Ya Zhou · Zhi-AngWu	2009	An adaptive algorithm for QoS-aware service composition in grid environments	Service Oriented Computing and Applications, 2009 - Springer
Zheng, Zibin - Lyu, Michael R.	2008	A QoS-Aware Middleware for Fault TolerantWeb Services	2008 19th International Symposium on Software Reliability Engineering (ISSRE)
Diego Zuquim Guimarães Garcia, Maria Beatriz Felgar de Toledo	2006	A Web Service Architecture Providing QoS Management	Web Congress, 2006. LA-Web '06. Fourth Latin American
Dunlu Peng, Qingkui Chen	2009	QoS-aware Selection of Web Services Based on Fuzzy Partial Ordering	2009 International Conference on E-Business and Information System Security, EBISS 2009
Cardellini, V-Casalicchio, E-Grassi, V-Lo Presti, F-Mirandola, R	2009	QoS-driven Runtime Adaptation of Service Oriented Architectures	ESEC-FSE'09 - Proceedings of the Joint 12th European Software Engineering Conference and 17th ACM SIGSOFT Symposium on the Foundations
Valeria Cardellini, Emiliano Casalicchio, Vincenzo Grassi, Francesco Lo Presti	2007	Flow-Based Service Selection forWeb Service Composition Supporting Multiple QoS	Proceedings - 2007 IEEE International Conference on Web Services, ICWS 2007

		Classes	
Alan Colman, Linh Duy Pham, Jun Han, Jean-Guy Schneider	2006	Adaptive Application-Specific Middleware	Proceedings of the 1st workshop on Middleware for Service Oriented Computing
Golshan, Farnoush - Barforoush, Ahmad Abdollahzade	2009	A New Approach for Tracing Quality Attributes in Service Oriented Architecture Using Graph Transformation Systems	Computer Conference, 2009. CSICC 2009. 14th International CSI
Mu Li, Ting Deng, Hailong Sun, Huipeng Guo, Xudong Liu	2010	GOS: A Global Optimal Selection Approach for QoS-Aware Web Services Composition	2010 Fifth IEEE International Symposium on Service Oriented System Engineering
Yau, S S - Ye, N - Sarjoughian, H - Huang, D	2008	Developing Service-based Software Systems with QoS Monitoring and Adaptation	Proceedings of the IEEE Computer Society Workshop on Future Trends of Distributed Computing Systems
Smit, M - Nisbet, A - Stroulia, E - Iszlai, G-Edgar, A	2009	Toward a Simulation-generated Knowledge Base of Service Performance	Proceedings of the 4th Workshop on Middleware for Service Oriented Computing, MW4SOC 2009 held at the ACM/IFIP/USENIX International Middleware Conference
Gang YE, Chanle WU, Jun YUE, Shi CHENG -	2009	A QoS-aware Model for Web Services Discovery	2009 First International Workshop on Education Technology and Computer Science
Bin Xu, Yixin Yan	2009	An Efficient QoS-driven Service Composition Approach for Large-scale Service Oriented Systems	IEEE International Conference on Service-Oriented Computing and Applications, SOCA' 09
M Agni Catur Bhakti, Azween B. Abdullah	2010	TOWARDS AN AUTONOMIC SERVICE ORIENTED ARCHITECTURE IN COMPUTATIONAL ENGINEERING FRAMEWORK	10th International Conference on Information Science, Signal Processing and their Applications (ISSPA 2010)
Nastaran Jafarpour, Mohammad Reza Khayyambashi	2009	A new approach for QoS-aware web service composition based on Harmony Search algorithm	2009 11th IEEE International Symposium on Web Systems Evolution, WSE 2009
Kyriakos Kritikos and Dimitris Plexousakis	2009	Requirements for QoS-Based Web Service Description and Discovery	IEEE Transactions on Services Computing
Hatvani, L- Jansen, A- Seceleanu, C- Pettersson, P	2010	An Integrated Tool for Trade-off Analysis of Quality-of-Service Attributes	Proceedings of the 2nd International Workshop on the Quality of Service-Oriented Software Systems
Wei Zhang, Carl K. Chang, Taiming Feng, Hsin-yi Jiang	2010	QoS-based DynamicWeb Service Composition with Ant Colony Optimization	2010 IEEE 34th Annual Computer Software and Applications Conference
Yau, S S- Ye, N - Sarjoughian, H S- Huang, D- Roontiva, A -Baydogan, M -Muqsith, M A	2009	Toward Development of Adaptive Service-Based Software Systems	IEEE Transactions on Services Computing
Loyall, Joseph P-Gillen, Matthew-Paulos, Aaron-Edmondson, James-Varshneya, Pooja-Schmidt,-Douglas C-Bunch, Larry-Carvalho, Marco-Martignoni, Andrew	2010	Dynamic Policy-Driven Quality of Service in Service-Oriented Systems	2010 13th IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing
Litoiu, M- Mihaescu, M- Solomon, B- Ionescu, D	2008	Scalable Adaptive Web Services	Proceedings - International Conference on Software Engineering
GuijunWang Alice Chen ChangzhouWang Casey Fung Stephen Uczekaj	2004	Integrated Quality of Service (QoS) Management in Service-Oriented Enterprise	Proceedings. Eighth IEEE International Enterprise Distributed Object Computing Conference, 2004. EDOC 2004.

Architectures			
Ponnalagu, Karthikeyan - Krishnamurthy, Jayatheerthan R.	2007	Aspect-oriented Approach for Non-functional Adaptation of Composite Web Services	2007 IEEE Congress on Services (Services 2007)
Liang-Jie Zhang, Ali Arsanjani, Abdul Allam, Dingding Lu, Yi-Min Chee	2007	Variation-Oriented Analysis for SOA Solution Design	SCC 2007. IEEE International Conference on Services Computing, 2007
Srnaivas Padmanabbuni, Bijoy Majumdar, Mohit Chawla, Ujval Mysore	2006	A Constraint Satisfaction Approach to Non-functional Requirements in Adaptive Web Services	International Conference on Next Generation Web Services Practices
N. Yasemin Topaloglu and Rafael Capilla	2004	Modeling the Variability of Web Services from a Pattern Point of View	Web Services-Lecture Notes in Computer Science, 2004, Volume 3250/2004
Nanjangud C. Narendra, Karthikeyan Ponnalagu	2010	Towards a Variability Model for SOA-Based Solutions	2010 IEEE International Conference on Services Computing
Alessandro Bellucci, Valeria Cardellini, Valerio Di Valerio, and Stefano Iannucci	2010	A Scalable and Highly Available Brokering Service for SLA-Based Composite Services	SERVICE-ORIENTED COMPUTING-Lecture Notes in Computer Science, 2010
Gerardo Canfora, Massimiliano Di Penta, Raffaele Esposito, Maria Luisa Villani	2008	A framework for QoS-aware binding and re-binding of composite web services	The Journal of Systems and Software 81 (2008) 1754–1769 www.elsevier.com/locate/jss
Sonia Ben Mokhtar a, Davy Preuveneers, Nikolaos Georgantas, Vale Yolande Berbers	2008	EASY: Efficient semAntic Service discoverY in pervasive computing environments with QoS and context support	The Journal of Systems and Software 81 (2008) 785–808
Bleul, S, Zapf, M, Geihs, K	2007	Flexible Automatic Service Brokering for SOAs	10th IFIP/IEEE International Symposium on Integrated Network Management 2007, IM '07
Pedro Furtado, Celso Santos	2007	Extensible Contract Broker for Performance Differentiation	International Workshop on Software Engineering for Adaptive and Self-Managing Systems (SEAMS '07)
Xiao-Ling Wang, Sheng Huang, Ao-Ying Zhou	2006	QoS-Aware Composite Services Retrieval	JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY, Volume 21, Number 4, 547-558