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a tertiary study**

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Thematic mapping of cloud computing based on a systematic review: a tertiary study

Thematic
mapping of
cloud
computing

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Abstract

Purpose – A large number of systematic reviews (SRs) studies have been performed in the cloud computing field, demonstrating miscellaneous outcomes and utilizing different approaches. Accordingly, a meta-review of cloud SRs is needed to appraise the results of such studies and create an integrated understanding. The paper aims to discuss these issues.

Design/methodology/approach – A tertiary study was conducted using a systematic method to analyze SRs including two stages: searching and screening the SRs and thematic synthesis of results. As a qualitative data management tool, Nvivo software was used to support the research process, for data coding and synthesis.

Findings – First, by searching electronic sources between the year of 2011–2016, out of a total of 142 identified articles, 94 articles were included according to pre-determined criteria, of which 76 articles were approved after qualitative evaluation. In the second stage, identifying the research themes, a map of the concepts and issues related to each theme was drawn up. The analysis shows that the quality of articles has improved but can be further enhanced using methodological guidelines as well as supporting tools. The research has focused more on the technical aspect, although there is an equal demand for synthesizing of cloud governance concepts.

Originality/value – This is the first tertiary study which presents the main research themes and concepts of cloud SRs in form of thematic maps by using the thematic synthesis and SR methods. This paper also provides some recommendations to improve reviews after evaluating the quality of papers. This study can support reviewers for future SRs in the field and also helps practitioners and managers to have a better understanding of different aspects of cloud computing.

Keywords Governance, Cloud computing, Systematic reviews, Thematic synthesis, Tertiary study

Paper type Literature review

1. Introduction

Cloud computing is considered one of the most important advances in the history of computing, resulting in a significant shift in how IT services are developed and deployed (Marston *et al.*, 2011). Cloud computing has attracted the attention of many academic and business communities (Bayramusta and Nasir, 2016) and, as a result, many types of research and reports have been published indicating various directions for the future. One popular kind of study among cloud researchers is the systematic review (SR), used to explore various cloud computing issues. SRs are generally used to understand, assess and synthesize the results of all existing studies in relation to a specific research domain



(Keele, 2007). Contrary to the traditional and conventional literature review, SRs are conducted using a well-defined and step-by-step research methodology (Kitchenham *et al.*, 2010).

Nevertheless, despite a large number of review studies published in the field of cloud computing, different interpretations and conclusions, even in relation to similar subjects or research questions, can be found. Moreover, each secondary study focuses on a certain aspect, resulting in a lack of an overall overview. This makes it difficult for researchers, policymakers and stakeholders to rely on and make decisions based on these results. As such, one main question is whether these SRs have been conducted using an accurate or precise methodology, resulting in consistent and coherent results. Responding to this question requires systematic research in the form of an overview of reviews (Paré *et al.*, 2015) or tertiary study (Garousi and Mäntylä, 2016). These kinds of studies aim to systematically review secondary studies to obtain a general view of the status quo in a specific research area (Garousi and Mäntylä, 2016). Such studies can help cloud newcomers discover what is happening in a given research environment (Kitchenham and Brereton, 2013). Typically, such studies are conducted if sufficient secondary studies are available. In this study, we refer to tertiary study as SR research, in which SR publications conducted in a common area were identified and evaluated, intends to provide a general view of how they are performed or what they achieved while addressing the particular issues.

Accordingly, the purpose of this tertiary study is to appraise and interpret cloud SRs from two points of view: methodological and contextual. In the first perspective, by assessing the methodological quality of the SRs, we seek to answer the question of whether these articles have been performed based on a precise systematic method. Additionally, the quality trend of SRs and the affecting factors on the quality of SRs are also analyzed in this perspective. In the other perspective, the content and results of SRs are reviewed and analyzed to obtain a comprehensive and integrated map of the essential dimensions and concepts in the field. Synthesizing the results of cloud SRs, we also intend to discover the relationships between the concepts and themes and display them using the thematic maps. This analysis also helps us to ensure the consistency between the results of the SRs. We believe that this study may be considered a guideline for future SRs in the field, as well as assisting cloud practitioners and managers to make decisions in the cloud market based on high-quality evidence.

The structure of this paper will be as follows. Section 2 briefly reviews tertiary study approaches as input for our study. In Section 3, the research methodology is described step by step. In Section 4, the most important findings are presented in relation to the research questions. Subsequently, in Section 5 we discuss the results obtained, while in Section 6, conclusions are drawn.

2. Cloud computing and tertiary studies

Cloud computing refers to the use of remote servers over the internet to store and process data (Castelino *et al.*, 2013; Alshamaila *et al.*, 2013). Cloud computing is a way to make computing resources more flexible in which increase the computing capacity or to add capability on the fly (Knorr and Gruman, 2008). Typical benefits are related to the outsourcing of the control, maintenance of the cloud, flexible access to capacity, which could result in potential cost-savings and better cost control (Janssen and Joha, 2011). Often contracts are made by cloud computing users and providers. Cloud computing payment can be based on the actual capacity used or subscription based. Apart from contractual governance also relationship governance between the user and provider is a key aspect (Loukis *et al.*, 2019).

We were not able to find any tertiary studies in the field of cloud computing at the time of this research. In this section, we thus review tertiary study approaches in the domains of software engineering and information systems to understand the process of conducting such research in a different but related field. Table I lists related tertiary studies in the two areas of software engineering and information systems undertaken between 2007 and 2016.

Focus	Topic/Purpose	Time span	Included SRs	Tertiary studies
Contextual	Explore the impact of systematic literature reviews in SE	2004–2007	20	Kitchenham <i>et al.</i> (2009)
Methodological/ contextual	Explore the impact of systematic literature reviews in SE (updating study (Kitchenham <i>et al.</i> , 2009; Kitchenham <i>et al.</i> , 2010))	2008–2009	67	Da Silva <i>et al.</i> (2011)
Methodological	Assess types and methods of synthesis in the review process and identify its challenges in SE	2005–2010	49	Cruzes and Dybå (2011b)
Contextual	Review and evaluate review studies in the field of distributed software development	2008–2012	14	Marques <i>et al.</i> (2012)
Methodological	Investigate the experiences of reviewers in conducting systematic research in SE	2005–2011	116	Imtiaz <i>et al.</i> (2013)
Methodological/ contextual	Assess the adoption, value and use of systematic research in software engineering compared with traditional literature review	2004–2010	148	Zhang and Babar (2013)
Methodological	Present a typology of reviews	1999–2013	139	Paré <i>et al.</i> (2015)
Contextual	Systematic mapping of review research in the field of software testing	1994–2015	101	Garousi and Mäntylä (2016)
Contextual	Investigate research topics on agile software development in SE	1990–2015	28	Hoda <i>et al.</i> (2017)
Methodological/ contextual	Identify the main research areas of software process improvement and assess the quality of SRs	2004–2015	24	Khan <i>et al.</i> (2017)
Methodological	Review and analysis of qualitative synthesis methods in SE	2005–2015	328	Huang <i>et al.</i> (2018)

Table I.
List of tertiary studies related to the field of cloud computing

Three are related to information systems, while the rest are in the field of software engineering. The latter addresses the domains of agile software development (Dybå and Dingsøy, 2008; Hanssen *et al.*, 2011), distributed software development (Marques *et al.*, 2012), software testing (Garousi and Mäntylä, 2016) and risk assessment and mitigation in global software development (Verner *et al.*, 2014).

In the field of information systems, Paré *et al.* (2015) tertiary study present a typology of reviews. The study uses the term “umbrella review” to describe one type of study in which researchers addressing a particular research question attempt to synthesize relevant evidence from a variety of quantitative and qualitative SRs. The study also indicates that tertiary studies generally use a tool with clear criteria, such as GRADE[1] or AMSTAR[2] (tools also used in the present research), to evaluate the rigor and quality of systematic studies.

The tertiary studies can be divided into three categories based on their study focus: methodological, contextual or a combination of both. The studies in the first group usually seek to evaluate SRs regarding methodology and research processes. These studies attempt to identify the most critical methodological challenges and issues in conducting such research, as well as propose appropriate solutions (e.g. Kitchenham and Brereton, 2013). In this category, Cruzes and Dybå (2011b) and Huang *et al.* (2018) studies, which explored different types of synthesis methods used in SRs in software engineering, should be mentioned. These studies found that the SRs paid little attention to the synthesis method, while in most of the review studies with a specific synthesis method, “thematic synthesis” (the method used in this research) or “narrative synthesis” was applied. The second category is related to contextual studies, often aimed at identifying topics and concepts addressed in review papers in a particular domain. Several other tertiary studies have also addressed both contextual and methodological aspects. For example, a study by Zhang and Babar (2013) used a mixed-method approach, comparing the value and use of SRs with traditional literature reviews.

3. Research methodology

The previous section presented an overview of the most important aspects of conducting systematic research in fields related to cloud computing (information systems, software engineering). As a tertiary study, this article adopts a research methodology framework (adapted from (Keele, 2007; Fink, 2013; Bandara *et al.*, 2011; Levy and Ellis, 2006; Cruzes and Dybå, 2011a) which uses a three-layered iterative approach, including:

- Input/output: this layer specifies the input and output of each research step, including the digital libraries, the number of articles obtained in each step in the search and screening phase, and the default forms used to perform the steps.
- Research process: in this layer, the process of doing research, including the main phases and steps, along with the activities related to each of them is determined.
- Tools: software tools used to facilitate and support the research process and activities are specified in this layer.

This three-layered framework, consisting of the research steps, the outputs, along with the tools used in each step, is schematically mapped in Figure 1. Below, the research process, involving six steps classified into two main phases, is described step by step in subsections 3.1–3.6.

3.1 Research questions

In the first step of the review process, research questions need to be clearly formulated. Accordingly, the following research questions for this tertiary review were determined based on the objective of the study, which was the evaluation of systematic research from methodological and contextual perspectives:

RQ1. What is the methodological quality of the review papers published in cloud computing over the years? (Methodological view)

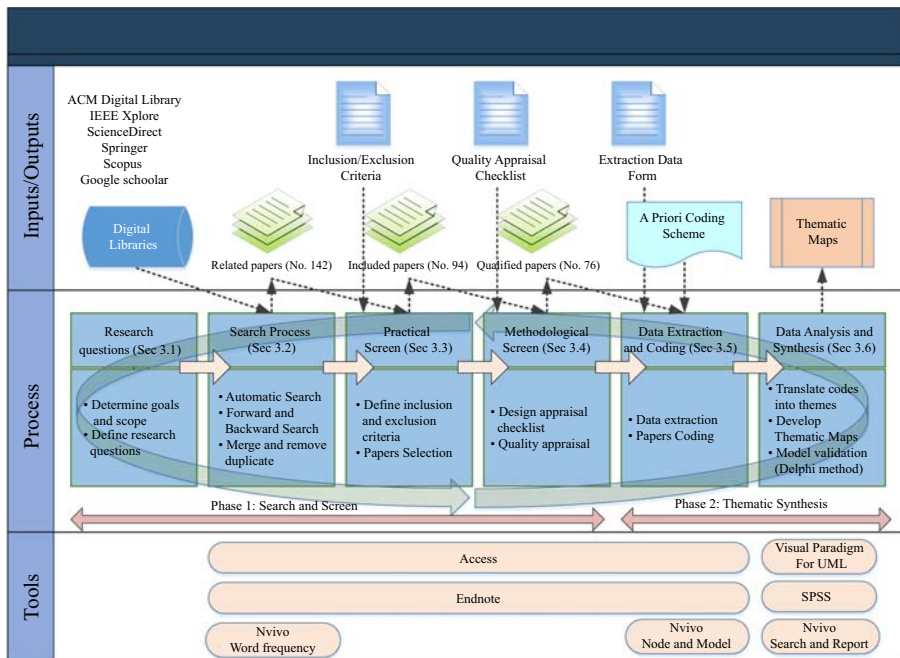


Figure 1. Research methodology framework

RQ2. What research themes and concepts have been addressed in cloud review papers? (Contextual view)

From the methodological point of view, attempts were made to evaluate the SRs identified, based on the type and method of research they employed, while the research topics addressed by the SRs were analyzed and evaluated from the contextual point of view.

3.2 Search process

After specifying the research questions, the search process needs to be detailed which involves two main activities: Automatic search and Forward/Backward search. In this study, the IEEE Xplore, Science Direct, Springer and ACM Digital Library were selected for the automated search process. Searches in Scopus and Google Scholar were also performed to ensure full retrieval of related articles. According to the method proposed by Zhang *et al.* (2011), the search string was defined as follows.

TITLE-ABS-KEY: (cloud computing) AND (systematic review) OR (mapping study) OR (mapping review) OR (systematic mapping) OR (scoping study) OR TITLE-ABS-KEY (scoping review) OR (meta-analysis) OR (review of studies) OR TITLE-ABS-KEY (in-depth survey) OR (structured review).

After conducting an automatic search and reviewing the documents based on the title and abstract, 137 related articles were retrieved. Then, undertaking a backward and forward search according to Levy and Ellis (2006), Webster and Watson (2002), 22 documents were added to the sample. Totally, after aggregating the articles obtained in the search process and the removal of duplicates (17 articles), 142 articles were considered relevant.

3.3 Practical contextual screen

Practical screening includes two basic measures: defining inclusion and exclusion criteria according to the research questions (Keele, 2007) and deciding on the inclusion and or exclusion of documents identified in the previous stage based on the specified criteria by reviewing the full text of papers (Brereton *et al.*, 2007). Criteria proposed by Fink (2013), Okoli and Schabram (2010) were used in this research to fulfill the first measure (Table II). As a result, out of 142 articles identified in the previous stage, 94 were included.

3.4 Methodological screening

This subsection discusses the quality assessment of SRs, which requires the use of a valid and reliable tool. First, it is necessary to develop an evaluation checklist, including clear and precise questions. Thus, this study defined ten specific questions (see Appendix I) based on AMSTAR[3] (Shea *et al.*, 2009) to assess the methodological quality of review articles. It then categorized the questions according to the three steps in an SR process as proposed by

Criteria	Inclusion	Exclusion
Content	The main focus on cloud computing	Review other subject related to cloud computing
Research design (review type)	Systematic literature review Mapping (scoping) study, meta-analysis	Traditional literature review citation analysis bibliometric analysis of literature
Context	Software engineering, IS, computer science, management, social science	Medicine
Publication language	Only studies in English	Other languages
Date of publication	Published from 2009 to 2016	Before 2009
Document Type	Conferences, journal article	PhD and Master's theses, other reports

Table II.
Inclusion and
exclusion criteria

Keele (2007): planning, conducting and reporting. Finally, review articles were evaluated by the authors using this checklist and consequently, 76 papers were qualified. The results of this activity are presented in Section 4.1.

In the following, the research activities related to the second phase of the study (i.e. thematic synthesis), including data extraction, coding and synthesis are described according to Thomas and Harden (2008), Cruzes and Dybå (2011a).

3.5 Data extraction and coding

Data extraction is a key component of SRs (Cruzes and Dybå, 2011a; Rousseau *et al.*, 2008), in which useful information is systematically extracted from the studies identified (Okoli and Schabram, 2010). Here, to increase the accuracy of the data extraction, a structured template (Cruzes and Dybå, 2011a), including three parts of the publication, the context and article findings were used. Afterward, the coding took place, which involves selecting, tagging and assigning a group of words to specific nodes to retrieve and analyze them (Bazeley and Jackson, 2013). According to Cruzes and Dybå (2011a), Burnard *et al.* (2008), coding can be done on the basis of three approaches: deductive (start with the initial list of concepts), inductive (no predefined codes) or an integrated approach. Taking the integrated approach, it is necessary first to define the coding scheme *a priori*, which is an initial classification model of the most important cloud concepts and aspects. In this study, the model (see Appendix 2) was designed based on the most popular and well-known studies (e.g. Marston *et al.*, 2011), as well as some expert opinions. The three main themes emerged from the analysis by following a coding process in which the authors read through the data several times and started labeling the concepts (Holton, 2007). Based on the labeling we arrived at three main themes and their accompanying subcategories. This was a non-linear and recursive process in which the authors discussed their concepts and over time the themes appeared. Subsequently, coding was conducted by two coders independently, based on clear, predefined protocols and rules. Nvivo software was used to complete the coding process, providing us with a set of tools for managing, querying, visualizing and reporting on qualitative data (Bazeley and Jackson, 2013; Burnard *et al.*, 2008).

3.6 Data analysis and synthesis

The purpose of this activity is to analyze the coded content with the aim of addressing the research questions. This includes three steps. The first is the process of translating codes into concepts and themes, i.e. reducing the number of codes to fewer, more meaningful sets. Consequently, three research themes and 13 concepts were identified through this activity. The second step attempted to further explore and interpret the concepts and themes and the relationships between them to achieve a higher level model of the concepts, which is also called a thematic map. The thematic map, which is a visual representation of the concepts, topics and relationships between them, assists in the interpretation and comparison of the results of the review studies identified. In this study, these maps were drawn using a “UML Class Diagram”, which will be described in more detail in Section 5.

The third step in the thematic synthesis is to measure the trustworthiness of the study results and validate them. In this regard, a three-round Delphi survey (Hsu and Sandford, 2007) of twelve academic and industry experts[4] – who were selected based on specific criteria, such as knowledge and experience in the field, willingness, sufficient time to participate and practical communication skills – was conducted. In the first round, a questionnaire consisting of open-ended questions (see Appendix 3) was designed and distributed among the experts to identify their general ideas. In the second round, expert opinions about concepts and themes identified in previous steps were obtained using a five-point Likert-scale questionnaire. In the final stage, the experts were asked about the relationships identified in thematic maps of the concepts approved in Round 2, again using a five-point Likert scale.

4. Findings

This section describes the results of this study based on the questions determined in subsection 3.1. The number of review studies included, published between 2011 and 2016 is shown in Figure 2. Out of a total of 142 identified articles, 94 were initially included (see Appendix 4)[5], of which 76 met the final criteria after evaluating the quality of included review papers based on the AMSTAR assessment checklist. The annual trend in publications shows the increasing interest of researchers in conducting SRs in the field of cloud computing. In the following, the results of quality evaluation of SRs related to the first phase of the study are provided in Section 4.1, while in Section 4.2, the analysis of the thematic synthesis or coding process were presented using the Nvivo software reports.

4.1 RQ1: the methodological quality of the review studies

As mentioned in subsection 3.4, the quality of the papers included in this study was evaluated using a reliable tool. Figure 3(a) shows the average quality of the papers and also the three main stages of the review, namely, planning, conducting and reporting by year (2011–2016), based on the results obtained from the qualitative appraisal of the review papers[6]. Based on this figure, the quality of papers has grown on average over the years, regarding both the total quality and the quality of each stage (with an average growth of around 20 percent for the total quality). This result indicates that in recent years, by increasing the number of SR papers published in the field of cloud computing, cloud reviewers have gained more knowledge and experience about SR methods.

In addition, we also identified the software tools used in the review papers to support the research process, which were divided into five main categories, as shown in Figure 3(b). These tools were only used in 14 articles, indicating that scholars are currently not interested in using such software or have little knowledge about their application. By comparing the two groups (those who used software and those who did not), it can be concluded that the use of software tools may improve the quality of review research. This may also be true for articles that use reliable and known references or guidelines to conduct their systematic research (see Figure 3(c)). It should also be noted that the mean quality of the articles published in journals is better than conference papers[7] (see Figure 3(d)).

4.2 RQ2: the main themes and concepts of review studies

To answer this research question, review articles were studied to determine the most crucial research themes in the field of cloud computing. These were found to be technology, business and governance. Figure 4, which was created using Nvivo software, displays the coded content (the number of words coded) for each theme per year of the articles published. Approximately half (47.27 percent) of the content coded was related to technological issues,

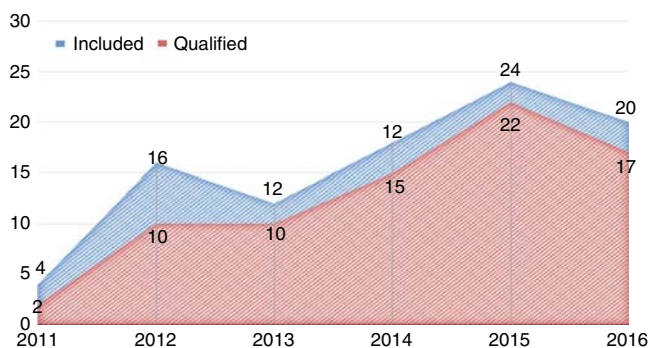


Figure 2.
Distribution of
review studies by
publication year

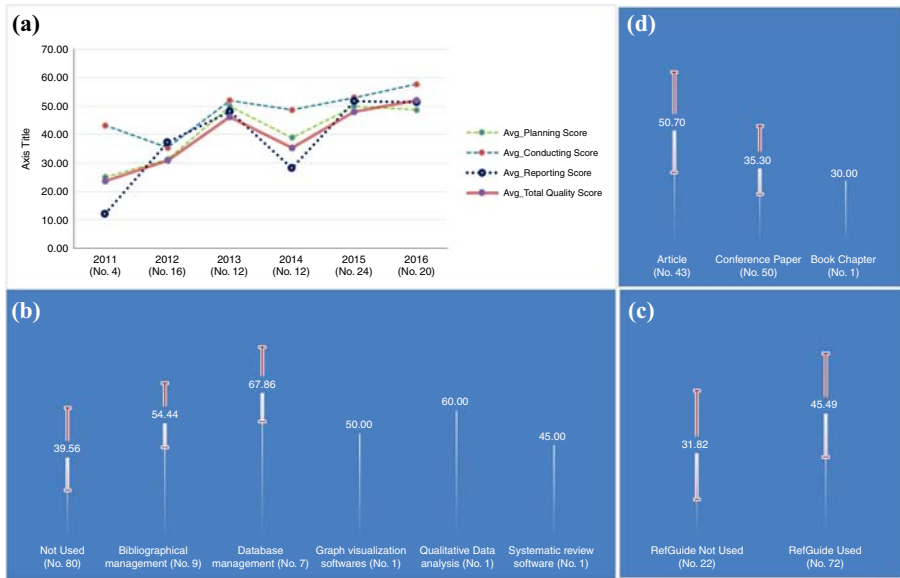


Figure 3.
The comparison of average quality by year

Notes: (a) Average quality by year; (b) use of software tools; (c) reference guides; (d) document types

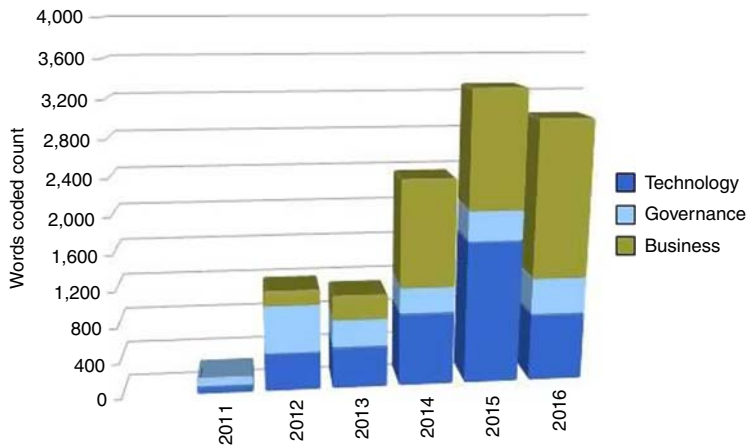


Figure 4.
Distribution of word coded in each theme per year

which indicates that most articles focus on this theme. It can be seen from the figure that, of the three main themes identified, relatively little attention was paid to governance issues.

In addition, Using the Nvivo software, we analyzed and compared the number of review articles that addressed the concept, or, in other words, were coded corresponding to the concept. The findings of this analysis along with the short description of each concept can be seen in Table III. Thus, the concepts of resource management, service level management and security and privacy have attracted the most attention of reviewers, while the concepts of trust, culture and people and risk management have received the least attention from reviewers.

Concepts	Description in cloud literature	No. of SRs coded
Resource management	The process of cloud resource provisioning and scheduling in an efficient manner according to quality-of-service required by the cloud customer	63
Service level management	The process of defining the quality of service parameter, SLA negotiation and service level monitoring and reporting in cloud environments	56
Security and privacy	Identifying the main threats and vulnerabilities related to confidentiality, integrity and availability of information and service as well as providing solutions to deal with them in cloud areas	50
Cloud architecture	Designing the various components of the cloud and the relationships between them to use cloud resource and meet the business needs	49
Financial and economic issues	Considering and examining the economic aspects of cloud computing such as accounting, pricing and billing, cost and benefit analysis	45
Application management	Designing, migrating, development and testing of cloud applications and software	44
Adoption	Investigating the factors affecting decision making on migration to cloud solutions as well as identifying the process of how to perform it	41
Vendor management	Identifying and studying different approaches for selecting and evaluating cloud service providers as well as auditing of service to avoid vendor dependency and increase the quality of service	36
Organizational alignment	Changing organizational processes and policies and adjusting roles and responsibilities to facilitate a better fit of the organization into a new cloud environment	30
Legal and regulatory issues	Refer to providing explicit laws and regulations as well as monitoring compliance with them for the governing cloud environment	28
Trust	Studying the factor affecting the level of customer confidence in using a cloud service	25
People and culture	The study of individual and social factors of human in the cloud ecosystems such as people expertise and knowledge or their attitude toward the cloud	21
Risk management	The process of identifying and assessing risk elements and setting the policy and procedure to mitigate them in relation to the cloud environment	12

Table III.
Concepts compared by
the number of review
articles code

To determine the relationship between cloud concepts and themes, a Sorensen correlation coefficient between concepts was calculated based on the word similarity of the node (i.e. concepts and themes). The results of this analysis are presented in a cluster diagram (Figure 5), in which nodes with a higher coefficient (i.e. having many words in common) are placed in clusters closer together. In addition, as a sample, the correlation coefficients obtained for some clusters which have relatively higher values than the rest of the clusters are also shown in the figure. The interesting point of this analysis is that concepts can be grouped into three main clusters, including red, green and purple boxes (as specified in Figure 5), which show the concepts related to the three themes identified: technology, business and governance, respectively.

In the following, the results of quantitative analyses related to the second and third rounds of the Delphi method are described. In the first round, a one-way ANOVA statistics test[8] was conducted to examine the relationship between each of the concepts and the themes identified. The results of this test (Table IV) show that the null assumption is rejected[9] for the eight concepts, which means that there is a significant difference between the means of the responses for the concepts linked to the themes of technology, business and governance. In other words, from the experts' point of view, these concepts are not considered to be related to all three of the themes identified. By observing the concepts' average score for responses in different themes, the concepts whose average score was less than 3.00 were excluded from the corresponding theme. In the third round, a one-sample *t*-test[10] was used to confirm the relationships between concepts identified in each field.

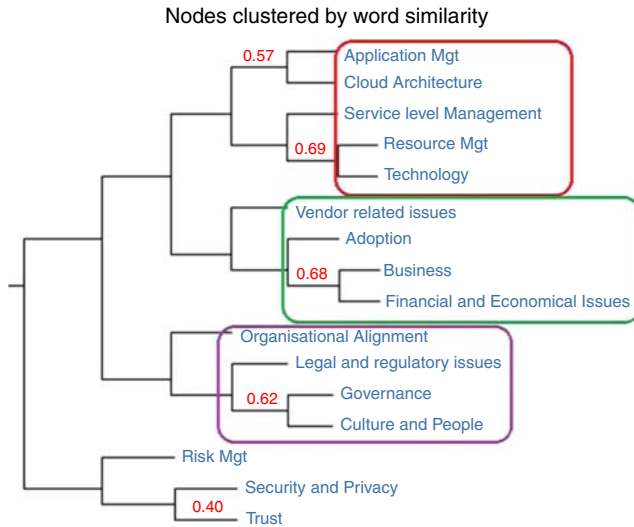


Figure 5.
Concepts clustered by
word similarity

Concepts	Mean			Sum of squares	df	Mean square	F	Sig.	H_0	Overarching theme
	T^a	B^b	G^c							
Adoption	3.86	4.15	3.92	0.06	2	0.03	0.04	0.96		T, B, G
Service level management	4.02	4.17	4.00	0.22	2	0.11	0.17	0.85		T, B, G
Resource management	4.17	4.00	2.17	29.56	2	14.78	20.90	0.00	Rejected	T, B
Security and privacy	4.19	3.75	4.16	1.17	2	0.58	0.78	0.47		T, B, G
Vendor management	4.18	4.25	4.17	0.06	2	0.03	0.04	0.96		T, B, G
Cloud architecture	3.83	2.75	2.08	18.72	2	9.36	8.87	0.00	Rejected	T,
Application management	4.00	3.83	3.83	0.22	2	0.11	0.15	0.87		T, B, G
Trust	2.50	4.17	2.58	21.17	2	10.58	9.82	0.00	Rejected	B
Financial and economic issues	2.58	4.18	2.17	24.39	2	12.19	13.64	0.00	Rejected	B
People and culture	2.08	1.83	4.08	36.50	2	18.25	21.90	0.00	Rejected	G
Organizational alignment	2.17	1.83	4.25	41.17	2	20.58	21.51	0.00	Rejected	G
Risk management	2.67	2.50	4.03	16.22	2	8.11	6.75	0.00	Rejected	G
Legal and regulatory issues	2.75	2.25	4.00	19.50	2	9.75	11.29	0.00	Rejected	G

Notes: ^aTechnology theme; ^bBusiness theme; ^cGovernance theme

Table IV.
The results of a one-way ANOVA statistics test (Delphi second round)

The results of this test indicated that there was a significant difference between the mean scores for responses of 3.00, which means all relationships identified were confirmed by the experts. Furthermore, to measure the degree of consensus among experts, Kendall's coefficient of concordance was calculated for the second and third rounds. At 0.52 and 0.86, respectively, it confirmed the agreement between the experts.

5. Thematic maps of cloud computing themes

In this section, we discuss the main results of the review studies based on the three themes of cloud computing identified: technology, business and governance. For each theme, the mostly related concepts and topics, as well as the relationship between them, are described

on the basis of the content coded in each review paper. These concepts, topics and the relationships between them are displayed in a conceptual model (thematic map) using a UML class diagram model for each theme.

5.1 The theme of technology

Technology has been considered by cloud researcher as the main issue affecting the adoption of cloud computing (Senyo *et al.*, 2016; Safari *et al.*, 2015; Gutierrez *et al.*, 2015; Gangwar *et al.*, 2015). The results of some review studies also show that most cloud research focuses on the technological aspects of cloud computing [R51, R59, R62, R67, R100]. Yang and Tate (2012) argued that cloud research on the theme of technology focuses on the details of cloud computing technology and its mechanisms and components. In their proposed business-technology framework, Marston *et al.* (2011) considered topics such as security standards and the design of IT auditing policies, as well as forensics related to the technical dimension of cloud computing. Data security and privacy, cloud infrastructure, virtualization and energy efficiency were among the issues considered to be related to the technical dimension by Upreti *et al.* (2016).

Based on the coding content of the review papers selected, the main concepts related to this theme and the relationships between them is presented in a class diagram (Figure 6). The diagram specifies each of the concepts identified for each theme as a class; the attributes of each class represent the topics discussed in the review research and the relationships between each of the concepts are also indicated by arrows. Furthermore, the figure also presents the statistical results obtained from the second (average responses for each concept) and third (*t*-statistic for the relationship between concepts) round of the Delphi method. Below, each of the concepts, the topics addressed and their input and output connections with other concepts will be explained in more detail.

5.1.1 Security and privacy. Review articles addressing security and privacy focus on two main issues. They seek to identify and present the most important requirements, threats and vulnerabilities related to the security and privacy of cloud computing, or provide mechanisms and solutions to deal with these threats. In this study, six papers [R5, R35, R45, R86, R89, R95] were identified as review studies conducted specifically on the subject of security. One study [R5] stated that there is no specific adaptive approach covering all of the conditions associated with security issues. Another study [R35], which categorized the kinds

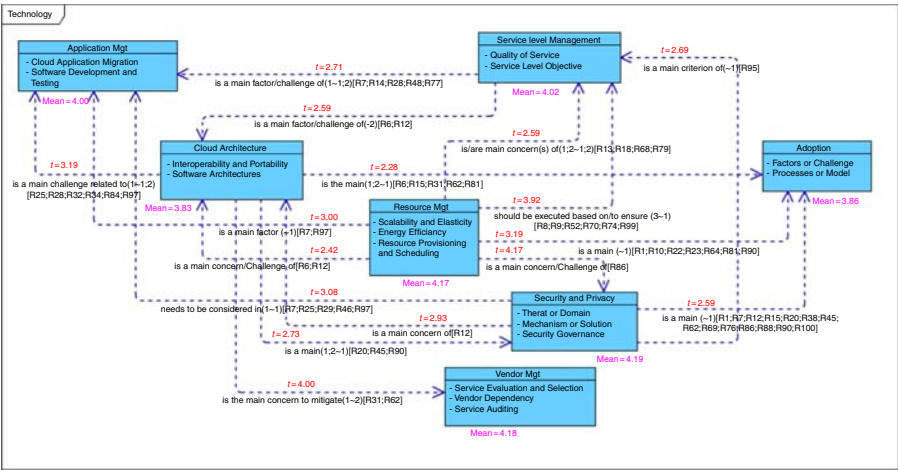


Figure 6. Technology: thematic map

of security requirements, found that most articles focused on access control, integrity and auditability topics. Presenting a similar categorization, [R45] reviewed the most essential security goals and issues, in which data protection, access management and software isolation were identified as the most frequent topics. [R95] reviewed papers related to the field of cloud security based on CSA[11] security threats and found that most articles addressed two types of threat related to unknown risks and shared technologies. In [R90], the most critical security challenges in cloud computing were categorized into five groups: trust, architecture, identity management, software isolation and data protection.

5.1.2 Resource management. The special characteristics of cloud environments, such as heterogeneity, dynamism, uncertainty and dispersion of resources, make the management and allocation of resources a challenging and difficult task [R8]. Two studies [R52, R70] define resource management as an overall activity which consists of various steps. These two review studies were conducted in relation to two different stages in resource management, including resource provisioning and resource scheduling. In these two studies, as well as [R8], “QoS-aware” and “self-management” (“autonomic management”) of cloud services were referred to as two main aspects of cloud resource management.

In general, these review studies emphasized that cloud resource management should be based on the quality of the service. Scalability and elasticity, considered two of the most essential characteristics of cloud services, have drawn the attention of many researchers in the literature on cloud resource management. Specifically, two review studies [R18, R79] that conducted SRs of articles related to these two concepts, indicated that these two features should be carefully considered by the service level management as factors affecting the quality improvement of cloud services. Energy consumption and costs were also significant issues in cloud resource management research. In this regard, we found two review studies [R13, R68], in which papers related to energy efficiency in two areas of network and software architecture were analyzed.

5.1.3 Cloud architecture. Cloud architecture means designing and engineering the various components and elements of cloud computing and the relationships between them to take advantage of the potential of cloud resource to meet the business needs. In this study, we identified several review articles, including [R6, R12, R13, R16], which directly addressed cloud computing architecture. One review study [R6] focusing on the concept of software architecture described the design, evaluation and implementation of cloud-based software architecture as one of the most significant challenges of cloud computing. “Interoperability” and “portability” are two other important concepts in the literature on the cloud and have been described in review articles using various forms and terms related to architectural issues. In some review studies, the lack of interoperability and portability of cloud services was considered as the main reason for vendor dependence, or what some call vendor “lock-in” [R9, R12, R25, R31, R62]. According to the results of the review studies, cloud standardization [R31, R62], the use of architectural reference models and structured design methods [R12], as well as the use of semantic web technology [R81], are among the most important ways to enhance interoperability and portability and reduce dependence on cloud providers.

5.1.4 Application management. Two relevant topics were identified in relation to this concept, namely cloud applications migration and software development and testing. Regarding cloud applications migration, the results indicate that research in this area is in its early stages but is progressing [R14, R29, R48]. [R14] defines it as the migration of an application from an internal platform to a cloud provider environment with the ability to reuse components compatible with the cloud environment. Several other terms and expressions such as “legacy or software modernization”, “adaptive maintenance or modification for a new environment” [R29] and “re-engineering process of legacy applications” [R97] have been used to define it. Some of the studies have also reviewed and

categorized research according to the process and stages of cloud migration [R7, R14, R29]. Based on their results, the largest number of studies performed relate to the stage of the migration planning. Furthermore, four review articles [R7, R29, R48, R97] studied various types of cloud migration, all of which identified four forms: “replace”, “partially migrate”, “migrate the whole” and “cloudify”.

Software development and testing in a cloud environment is another topic related to application management that has attracted the attention of cloud reviewers. Two similar review studies conducted in the area to software design and engineering in the cloud environment identified the main challenges of software development, which included data lock-in, Cloud Service Composition, the re-engineering process [R32], software reusability, standardization and software testing [R28]. Software testing has been addressed in cloud research reviews under two main topics: “software testing for the cloud” and “testing in the cloud” [R28, R34, R84]. One of the main advantages of software testing in cloud computing, as described in the review studies, is a significant reduction in human costs and errors [R34, R84]. [R84] concluded that there is a lack of standards to support connectivity and interoperability for software testing tools and techniques in cloud computing.

5.1.5 Service level management. Given the fact that cloud computing is based on providing services through external providers, service level management is critical for quality assured service delivery. Accordingly, many review articles describe the challenges and research gaps associated with this concept. [R9] focuses on the resource allocation phase of the service level agreement (SLA) life cycle. The study found that the lowest number of SLA parameters was considered by most researchers in this field. The findings of other review studies highlight the importance of SLAs and the quality of service (QoS) as important factors both in software design and testing [R28, R77] and also in the process of migrating applications [R7, R14, R48] to the cloud. [R28] also introduced QoS as one of the research areas in the design and development of software, identifying its most important metrics, including reusability, efficiency, reliability, scalability and availability. In [R14], response time and violation of the SLA were introduced as the main QoS criteria. Another advantage of using the SLA approach is to improve data integrity in multi-cloud environments [R87]. [R44] emphasized the need for approaches, tools and applications to monitor the customers’ expected QoS in cloud computing.

5.2 The theme of business

Yang and Tate (Yang and Tate, 2012) identified research that they considered took a “black-box approach” to cloud technology and emphasized the importance of creating business values for both providers and consumers. The results of the review studies reveal a relative lack of research on the business theme compared to technology [R64, R67, R82], which can be attributed to the need to address the technical challenges in the early days of cloud computing [R67], as well as to the growth and rapid development of this technology [R82]. According to the findings of some primary (Marston *et al.*, 2011; Bayramusta and Nasir, 2016) and secondary studies [R7, R60, R64], economic aspects, including cost and pricing strategies are among the most important components of the business dimension. Adoption is another concept that has been studied by cloud researchers from a business perspective (Upreti *et al.*, 2016) [R64, R67]. Similar to the technology theme, the most important concepts of the business theme and their relationships are illustrated in Figure 7. Below, we will give a more detailed description of each concept.

5.2.1 Vendor management. Because organizations have to deal with multiple service providers in the cloud ecosystem, managing their relationships with them is very important. One of the issues related to this concept is the evaluation and selection of cloud services in accordance with the needs of organizations. This has become an important concern for

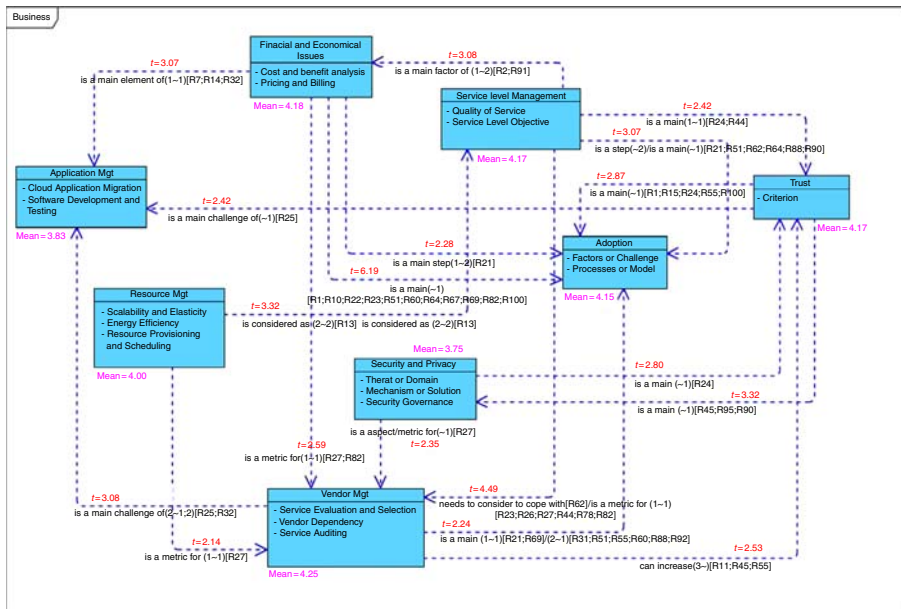


Figure 7.
Business:
thematic map

organizations due to a large number of services and their vendors in the cloud environment. Reviewing the results of the secondary studies [R26, R27, R78] shows that security, performance and cost are three key indicators in the evaluation and selection of cloud services while quantifying these criteria is a fundamental challenge in the evaluation of cloud services. The review literature does outline some approaches for selecting and evaluating cloud services, such as the use of the cloud service broker (CSB) [R21, R69, R82], which plays an intermediary role between consumers and suppliers, as well as applying ontology [R92] for the discovery and description of cloud services. In addition, according to the results of the review studies, vendor dependence in cloud computing is one of the most important challenges in adopting cloud computing [R31, R51, R55, R60, R88, R92]. This can be explained by the fact that after the deployment of a service in an organization, migrating to another service for various technical or economic reasons is simply not possible (which is known as vendor lock-in, mentioned above).

Another important issue related to this concept is the audit and monitoring of the services. The review studies [R11, R45, R55] suggest that the continuous auditing of services based on predetermined criteria, especially performed by neutral institutions and granting cloud services certificates, can have a significant effect, increasing the level of confidence and trust of cloud consumers in cloud services.

5.2.2 *Financial and economic issues.* The results of this study indicate that economic and financial issues related to the business aspect of cloud computing are of particular importance and are considered an important motivating factor for organizations to adopt cloud computing [R64, R7]. We identified two important issues related to this concept, concerning cost-benefit analyses for adopting and migrating to cloud computing and cloud pricing and billing models. One study [R21] defined cost-benefit analysis as entailing the evaluation and comparison of the costs against the benefits of migration to cloud computing in both the short and long term, based on specific parameters such as profitability, return on investment and hidden costs. Another study [R69] emphasized the importance of

cost-benefit analysis in the adoption of and migration to cloud computing, concluding that many factors had been used by organizations to measure the costs and benefits of cloud adoption, while there was no agreement about them.

The pricing and billing methods for cloud services is another topic related to this issue that is addressed by some review studies [R2, R82, R91]. One study [R2] emphasized the need to apply appropriate pricing techniques to ensure the success and sustainability of the cloud ecosystem. The research concluded that despite the fact that “fixed pricing” is a dominant model in today’s cloud market, many believe that the “spot pricing” method may play an important role in a mature market economy for the cloud ecosystem. Another study [R82] categorized the most important research areas and decision themes related to business dimensions of cloud computing, in which pricing had the highest frequency of papers. [R91] also studied accounting models and pricing schemes and found terms such as accounting, pricing and billing were commonly used synonyms related to this issue in the literature.

5.2.3 Trust. The results of several review studies show that trust is one of the most important indicators for the adoption of cloud computing [R1, R15, R24, R55, R100]. One study [R64] reviewed the articles in the cloud computing domain, presenting a taxonomy of cloud concepts, in which trust was introduced as one of the fundamental concepts in business. In another study [R45], trust was defined as the level of customer confidence in using a cloud service, which can be increased by resolving technical and psychological issues. A third study [R24] reviewed and compared the literature in cloud computing and on trust. In addition to pointing out that most of the criteria identified in the trust literature have been neglected by cloud researchers, this review also emphasized that most of the criteria were qualitative and high level. It is suggested that the criteria should be subdivided into quantitative and measurable indicators for a more accurate assessment of trust levels. Lack of trust is also considered a significant challenge to security and privacy in other review articles [R45, R95, R90]. One study [R1] noted that uncertainty between users and providers are higher in the deployment phase of cloud services due to factors such as data loss concerns. Another study [R90] stated that with the adoption of cloud services, organizations delegate the control and management of their services to cloud providers and, therefore, security processes and policies need to be applied to cloud providers.

5.2.4 Adoption. Most of the research that has focused on adoption has attempted to systematically review the most important factors, challenges or drivers of adopting cloud computing, among the most important of which are security, privacy, cost and trust [R1, R15, R21, R88, R100]. A number of other review studies have also focused on the processes and steps taken to deploy cloud computing and related models. For example, one study [R21] described the process of adopting cloud computing, including assessment, concept proofing, adoption decision, implementation and integration, IT governance and confirmation. The results of our study reveal that the public sector and small and medium-sized enterprises and organizations are the environments addressed in review studies related to cloud adoption.

5.3 The theme of governance

Cloud researchers emphasize that cloud governance, as a critical field of study of how organizations can effectively control their cloud services and infrastructure (Bounagui *et al.*, 2019) derived from the corporate and information technology governance, has become a key pillar of cloud computing (Owuonda and Orwa, 2016). They also stated that the paradigm shifts of information technology due to the emergence of cloud computing, has complicated the governance issue in dealing with technology and business factors (Prieto-González *et al.*, 2015) and as a result, the definition and identification of new approaches have been required (Becker and Bailey, 2014). Regarding this challenge, research has followed two different approaches, Some of which (e.g. Joha and Janssen, 2012; Saidah and Abdelbaki, 2015) consider

cloud governance to be a subset of IT governance and, accordingly, specifies the same activities and definitions while other research (e.g. Karkošková and Feuerlicht, 2016; He, 2011) considers cloud governance and SOA governance as two close and related concepts that have some characteristics in common (Jol, 2014), applying SOA governance standards and frameworks as the basis for designing cloud governance models. He (2011, p. 16) defined cloud governance as “a framework for the leadership, organizational structures and business processes, standards and compliance to these standards, which ensure that the organization’s cloud capability supports and enables the achievement of its strategies and objectives.”

Finally, governance was identified as a main theme of cloud SRs along with the themes of business and technology in this research. One review study [R60] introduced governance as an important dimension of the cloud, arguing that researchers in the field have paid little attention to this subject. This study found three main aspects related to governance: structure, process and employee. Another study [R25] also identified organizational challenges – which mostly related to the structure or level of organization, processes and people – as one of the two major categories of challenges for cloud migration. A third study [R41] introduced the three concepts of compliance, risk and security, as issues related to cloud governance, arguing that little research has been performed on these three topics in cloud computing. Their review study aimed to provide a reference model. In the following, similar to previous themes, we describe the results of our study, illustrating the concepts related to the theme of governance using a UML class diagram (Figure 8).

5.3.1 People and culture. This study found culture and people-related issues to be the main concern in the adoption of cloud computing [R15, R21, R51, R82], as well as in the migration of applications to the cloud [R7, R25]. Marston *et al.* (2011) introduced corporate cultural impact as an important research area in cloud computing, claiming that the cloud’s impact on organizational culture is a key factor in the success and failure of the cloud. By conducting a review study and categorizing articles based on Marston *et al.* (2011) framework one study [R82] considered culture as a cloud decision theme and defined it as a set of beliefs, values and attitudes of cloud providers, consumers and organizations.

Given the fact that cloud computing is a new technological trend, one study [R25] emphasized the need for the acquisition of new skills and expertise in organizations to migrate

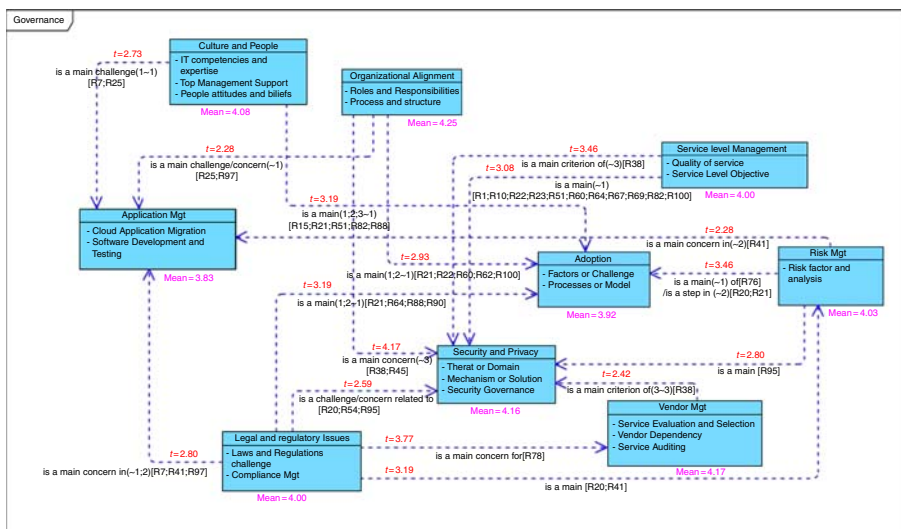


Figure 8.
Governance:
thematic map

to the cloud. [R21] categorized cloud adoption factors into internal and external categories and suggested that staff skills, along with management support and organizational culture, are important internal factors. Another similar study [R51] compared cloud computing literature with IT outsourcing literature, identifying the most critical factors in cloud decision making. These factors included top management support and people's attitudes towards outsourcing as two of the most influential factors found in both fields. Furthermore, in this study, no significant relationship was found between the institutional influences (the pressure based on shared values and norms to moderate the behavior of an employee within the organization) and the cloud outsourcing decision, in contrast to another study [R88], in which this factor was introduced as a driver of cloud adoption.

5.3.2 Organizational alignment. Organizational alignment which mostly considered as the main domain of cloud governance literature (Jol, 2014; He, 2011) refers to the changes in organizational processes and policies and the adjustment of roles and responsibilities for successful adaption of organization to cloud environment. A SR [R22] found that implementing cloud computing, depending on the company, required the organizational structure and processes to be fundamentally changed. The study points out that in the cloud environment, the responsibility of the IT department changes, from the operation, maintenance and support of IT services and infrastructure, to selecting the appropriate provider, SLA and service integration. Similarly, another study [R62] categorized articles in the cloud based on an IT business maturity model with three levels: business efficiency, business effectiveness and business transformation. The study suggested that organizations at the third level of maturity need to define new roles and responsibilities for the IT department, review IT governance structures and modify the business-IT alignment mechanisms to deal with the possible challenges.

The results of our tertiary study show that in some review studies [R38, R45] organizational alignment have been considered one of the critical components of information security governance. For example, one of the studies [R38] aimed to review and evaluate information security governance frameworks and considered policies and processes adaptation as one of the most appropriate criteria for comparing these frameworks. Some review studies [R25, R97] have also considered organizational alignment to be a critical concern in the migration of applications to the cloud. One review study [R97] proposed an evaluation framework for cloud migration approaches and introduced development roles as one of the general criteria for the comparison and classification of approaches. This study emphasized that the migration approaches should have newly defined roles and expertise related to the migration process.

5.3.3 Legal and regulatory issues. In the research reviewed in this study, two important legal issues were addressed: challenges to the enactment and enforcement of clear laws and regulations specific to the cloud and managing and monitoring compliance with cloud-related regulations and protocols. The results of the review studies show that legal and regulatory issues are of particular importance in the adoption of cloud computing [R21, R64, R88, R90], as well as cloud applications management [R7, R41, R97]. One study [R21] found the lack of proper government regulations and the inconsistency of international government regulations among the main obstacles to the adoption of cloud computing by organizations. In another similar categorization of barriers to cloud adoption presented in [R88], compliance was identified as one of the environmental factors. Another study [R41] indicated that software developers need a guide in their cloud computing environment to reduce their risk and manage compliance.

Based on the findings of the review studies [R20, R54, R95], it is clear that legal and regulatory issues are a determinant factor in relation to security and privacy in the cloud computing environment. One of these studies [R20] presented a categorization of security risks of the cloud from two perspectives: the cloud provider and cloud consumer, introducing "compliance and audit" as a category valid to both perspectives. One study

[R95] also examined the most relevant compliance standards related to the security approaches addressed by cloud researchers. The study found that CSA, ISO 27002, ISO 27001 and NIST were among the standards most frequently identified in review papers. Another study [R54] focused on international legal issues between large economies (in particular, the USA and Europe) in relation to data privacy, finding a meaningful difference in data protection regulations between the two economies studied.

5.3.4 Risk management. The findings of the review papers identified [R20, R21, R76] emphasize that organizations must prioritize and accurately assess possible risks before the adoption of cloud computing, as well as accurately define their policies on and mechanisms of risk management. One study [R95] introduced risk analysis and management as one of the most important areas of security in cloud computing. They defined “risk analysis” as “a set of policies to ensure the execution of security processes continuously and efficiently”. In a review study on cloud adoption [R21], risk management was considered a concept related to IT governance. This tertiary study found some other review studies [R20, R76] that examined risk identification and analysis in cloud computing. One of these studies [R76] focused on risk analysis in adopting cloud computing and identified security, confidentiality, auditability and regulatory compliance as the risks associated with cloud computing. The review explained risk management as involving three steps: identifying risk events, risks assessment and mitigating risks. Another review study [R20] also discussed and categorized the risks of cloud computing from the two perspectives of the cloud provider and cloud consumer, identifying five categories: organizational, technological, data security and privacy, physical security and compliance. As the results of these review studies show, security and compliance are significant concerns that should be taken into account by both cloud providers and consumers in a cloud environment.

6. Discussion

An overview of recent research on cloud computing in recent years has raised the need for a thorough review of the research. Accordingly, as a tertiary study, this research attempted to evaluate and analyses the review articles based on their methodological approach and contextual content. In the methodological evaluation, we found that the mean quality scores of the SRs was acceptable and improved over time. Most of the research (85 percent) have not used professional software tools, which we recommend for future SRs. In addition, this study revealed that the following guides and other references will also help researchers improve the quality of their review studies.

In relation to the contextual content, three central research themes – technology, business and governance – and 13 concepts were identified from cloud SRs. The thematic maps were related to each theme identified, presenting the main research concepts, topics and the relationships between them. Considering the identified themes, concepts and the relationships between them, the most critical research issues and findings of the review studies can be described as follows:

- Research issues related to the theme of technology: (T1) identifying cloud security challenges and providing solutions to them which can have a major impact on the adoption and migration of cloud application; (T2) providing flexible and scalable infrastructure resources with respect to the efficiency of energy consumption, QoS parameters and in accordance with the service level agreement; (T3) improving interoperability and portability between cloud services to reduce the dependence on cloud vendors and avoid vendor lock-in, using cloud technology reference models, cloud architecture standards and semantic web methods; (T4) examining and following the new processes, types, methods and approaches of migrating legacy applications to the cloud such as model-driven development and agile technique, the testing of cloud applications, and software testing using cloud-based tools and

solutions to reduce cost and human errors; (T5) specifying measurable criteria and applying novel tools and methods to assess the quality of service, manage service levels of cloud providers, and increase the trust level of cloud consumers.

- Research issues related to the theme of business: (B1) evaluating and selecting the appropriate service provider as well as monitoring their services based on the performance, security and cost criteria; (B2) performing cost-benefit analysis as a critical stage of cloud adoption process and applying new pricing methods for services; (B3) introducing methods for assessing and improving the confidence level of customers in the cloud environment specially to address security challenges and support cloud adoption; (B4) determining the factors promoting and challenges to cloud adoption and providing a process model for it.
- Research issues related to the theme of governance: (G1) improving IT skills and competencies, changing people's attitudes towards the cloud, and encouraging top management to support cloud migration and adoption; (G2) redesigning processes and structures, changing roles and responsibilities in accordance with the new requirements of the cloud environment such as comparing and choosing proper service providers, defining and negotiating service level agreement and designing service architecture; (G3) establishing appropriate legal rules, especially at the international level and monitoring compliance to regulations and standards; (G4) identifying and evaluating risks before adopting cloud computing, in particular in the areas of security and compliance

There are some challenges and limitations in conducting review studies that may affect the validity of the results of such research. Easterbrook *et al.* (2008) and Wohlin *et al.* (2012) discuss four forms of validity, which we address below:

- Conclusion validity: one of the major challenges for our review in this regard was identifying all secondary studies carried out in the field of cloud computing. Accordingly, as described in subsection 3.2, five well-known databases and Google Scholar were searched to ensure we found all of the relevant studies. In addition, valid search strings were defined and adapted for each digital database. Forward and backward searches were also used to ensure full coverage of resources.
- Construct validity: one of the challenges this research faced was the formulation of research questions that would cover all research areas of study. In this regard, we attempted to increase the accuracy and validity of the questions through research group meetings where we discussed the issues. The selection and screening of articles from identified sources by the authors was another potential source of bias in this research. Defining the precise criteria of inclusion/exclusion and taking multiple steps in the process using a group of researchers, aimed to mitigate the risk of this threat.
- Internal validity: regarding the use of thematic synthesis for data extraction and coding in this research, the primary challenge in relation to internal validity was the strong dependence of the results on the opinions and interpretations of coders (subjective or interpretive bias). Using clear and standard forms for data extraction, developing a coding protocol, the use of two coders independently, a random review and check of the codes by a third person and designing an *a priori* coding scheme based on the standard concepts derived from the literature, were among the most important ways to address this limitation. Additionally, the adoption of an approach which allowed coders to code content or article texts in several nodes at the same time substantially increased the validity of the research. Finally, the whole process of thematic synthesis was evaluated by an independent author using a checklist.

- External validity: this research only included articles published in English. In addition, due to time constraints, the research only focused on academic articles published in journals or given at conferences, therefore it does not include reports produced by industry. However, we obtained the opinions of academic and industry experts using the three-round Delphi method to cross-check the findings, in an attempt to overcome this limitation and increase the generalizability of the results of this research.

7. Conclusion and future work

This tertiary study brings clarity in the literature landscape, as SR studies performed in the cloud computing field, demonstrate miscellaneous outcomes and utilize different approaches. The most important newness of this study include identifying the research themes, concepts and topics addressed in cloud SRs and presenting their relationships using thematic maps. The three main cloud computing themes are technology, business and governance. By integrating the thematic synthesis and SR methods, we developed an iterative three-layered research framework for conducting such tertiary studies. We also evaluated the methodological quality of SRs in the field of cloud computing and suggested some solutions to improve it.

Relying on the results obtained from both perspectives, this study has implications for research and practice. In terms of methodological view, this study can be a reference guide for cloud reviewers, helping them understand how they can enhance the quality of their review research. For example, the results of this research show that a small number of review studies have used qualitative analysis and SR software (Figure 3). This study, therefore, encourages reviewers in applying these tools to facilitate and reduce the time and effort of the review process, especially in data extraction and analysis. In the contextual view, this study presented complete maps of existing literature of cloud SRs, providing research issues (as mentioned in Section 6) for cloud reviewers to focus on the proper cloud concepts and the relationships between them, which have been less addressed. In particular, as a few SRs have been conducted on the research issues including new procedure and roles for cloud application migration (G2), the impact of organizational culture and people skills on cloud adoption (G1), the ways to increase the trust level of customer in relation to security concerns (B3) and compliance management in cloud computing (G3), this study indicates the needs for further exploration.

Regarding the findings of contextual view, this study also has implications for business owner or managers, policy makers and regulators in cloud environments. In the current situation, organizations planning to migrate or recently migrated to cloud are faced with a large amount of information and services in the cloud environment which make them confused. By creating an evidence-based holistic view of cloud computing, this study can support the business owner and managers to fully realize the potentials of the cloud and make the right decisions. The study also helps policymakers and regulators to come up with a comprehensive understanding of the cloud and put in place the efficient and complete rules and policies for facilitating business in the cloud environments.

Finally, the results of this tertiary study show that, despite concerns about governance issues, both the technology and business aspects have been addressed more extensively in SRs on cloud computing. Therefore, there is a crucial need for analysis and interpretation of governance and management issues in cloud computing. Accordingly, in future research, we intend to conduct a SR that explicitly examines and focuses on governance issues and concepts in cloud computing.

Notes

1. The Grading of Recommendations Assessment, Development and Evaluation.
2. A Measurement Tool to Assess the Methodological Quality of Systematic Reviews.

3. A measurement tool to assess the methodological quality of systematic reviews.
4. Eight experts from six organizations working in the area of banking, health or insurance were selected. They are experienced in providing or consuming cloud services. For further details of expert information please see following link: https://docs.google.com/spreadsheets/d/1EKrYKMicXm1l_0coqveL2f_x5YxAWD4gCgtBQW2jnFQ/edit#gid=512035074
5. Please note that each review paper is marked with an identification code which is used to refer to them in the study.
6. For further details of quality appraisal results, please see following link: https://docs.google.com/spreadsheets/d/1EKrYKMicXm1l_0coqveL2f_x5YxAWD4gCgtBQW2jnFQ/edit#gid=512035074
7. To supports these findings, the statistical analyses (two independent sample *t*-test) were performed. These tests were used to compare the mean quality score of three groups of review studies: papers used software vs did not; followed a particular references guide vs did not; journal review article vs conferences review papers. For further details of the test results, in which all claims were confirmed, please see following link: https://docs.google.com/spreadsheets/d/1EKrYKMicXm1l_0coqveL2f_x5YxAWD4gCgtBQW2jnFQ/edit#gid=512035074
8. $H_0: \mu_{XT} = \mu_{XB} = \mu_{XG}$ (e.g. μ_{XT} : the mean of responses for concept *x* in technology theme).
9. Sig. (2-tailed) < 0.05.
10. $H_0: \mu_{XY} < = 3$ (μ_{XY} : the mean of responses for the relationship between concept *x* and concept *y*).
11. Cloud Security Alliance.

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Appendix 1

Review process	Id	Question	Answer
Planning	1	Has the preliminary design of the research (i.e. the definition of research questions and the inclusion criteria) been correctly stated before starting the research?	Yes, no, partially, cannot answer, na
	2	Has the process of selecting studies and extracting data accurately been performed (at least by two individuals)	Yes, no, partially, cannot answer, na
Conducting	3	Has the search process of studies been performed and reported comprehensively?	Yes, no, partially, cannot answer, na
	4	Has the included and excluded studies been listed completely?	Yes, no, partially, cannot answer, na
	5	Has the data of included studies been properly aggregated and presented (in form of a table, diagram, etc.)	Yes, no, partially, cannot answer, na
	6	Has the quality of studies been evaluated and reported based on the specified method and criteria?	Yes, no, partially, cannot answer, na
Reporting	7	Has the measured quality of the articles affected the results and findings of the research?	Yes, no, partially, cannot answer, na
	8	Has the appropriate method applied to integrate and present the research findings?	Yes, no, partially, cannot answer, na
	9	Has the publication bias or threats to validity been evaluated and stated explicitly?	Yes, no, partially, cannot answer, na
	10	Has the conflict of interest been clearly declared and acknowledged?	Yes, no, partially, cannot answer, na

Table A1. AMSTAR quality appraisal checklist

Appendix 2

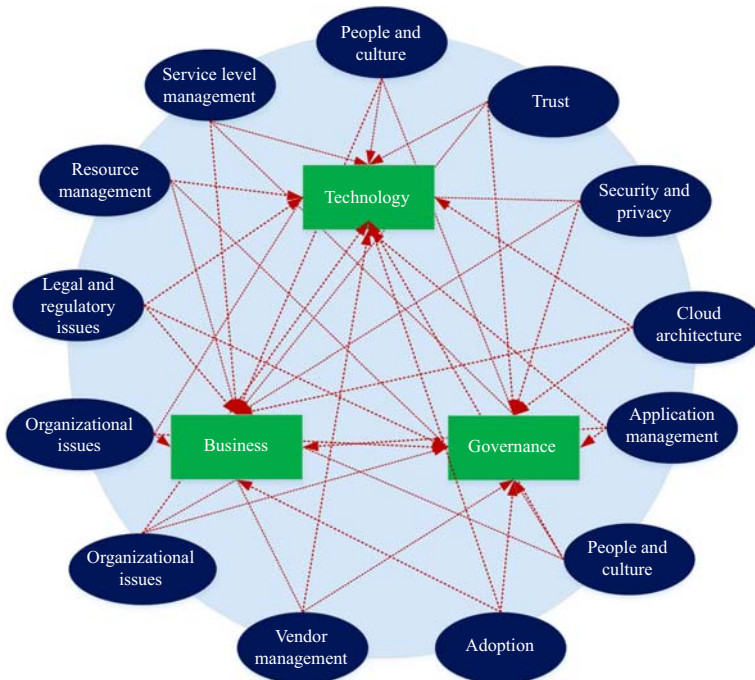


Figure A1. A priori coding schema

Appendix 3. Open-ended questions

- (1) According to you, what are the fundamental dimensions or categories key research areas should be considered by practitioners and researchers at the highest level in the field of cloud computing.
- (2) Conducting a systematic research review, we found three research themes of technology, business and governance. What do you think regarding these three research themes? Do you have any experience with the three themes that were mentioned?
- (3) what critical concepts or topics do you think can be classified under the technology theme?
- (4) what critical concepts or topics do you think can be classified under the business theme?
- (5) what critical concepts or topics do you think can be classified under the governance theme?

Id	Authors/year	Title	No of primary studies	Time-span
R1	Ali <i>et al.</i> (2016)	An investigation of the challenges and issues influencing the adoption of cloud computing in Australian regional municipal governments	90	2005–2014
R2	Li <i>et al.</i> (2016)	Spot pricing in the cloud ecosystem: a comparative investigation	61	2010–2015
R3	Hosseinzadeh <i>et al.</i> (2015)	Security and privacy in cloud computing via obfuscation and diversification: a survey	43	2009–2015
R4	Benslimane <i>et al.</i> (2015)	Key topics in cloud computing security: a systematic literature review	275	2009–2015
R5	Amoud and Roudiès (2016)	A systematic review of security in cloud computing	14	2009–2015
R6	Chauhan <i>et al.</i> (2016)	Architecting cloud-enabled systems: a systematic survey of challenges and solutions	133	2009–2015
R7	Rai <i>et al.</i> (2015)	Exploring the factors influencing the cloud computing adoption: a systematic study on cloud migration	23	2009–2014
R8	Singh and Chana (2015)	QoS-aware autonomic resource management in cloud computing: a systematic review	110	2009–2015
R9	Faniyi and Bahsoon (2015)	A systematic review of service level management in the cloud	106	Unknown
R10	Benslimane <i>et al.</i> (2014)	Key challenges and opportunities in cloud computing and implications on service requirements: evidence from a systematic literature review	132	2008–2014
R11	Lins <i>et al.</i> (2015)	What is really going on at your cloud service provider? Creating trustworthy certifications by continuous auditing	28	1981-unknown
R12	Breitvold <i>et al.</i> (2014)	Architecting for the cloud: a systematic review	72	Before 2013
R13	Procciantini <i>et al.</i> (2015)	A systematic literature review on energy efficiency in cloud software architectures	26	2008–2012
R14	Abdelmabou <i>et al.</i> (2015)	A comparative evaluation of cloud migration optimization approaches: a systematic literature review	25	2010–2014
R15	Wahsh and Dhillon (2015)	A systematic review of factors affecting the adoption of cloud computing for e-Government implementation	12	Unknown
R16	Lewis and Lago (2015)	Architectural tactics for cyber-foraging: results of a systematic literature review	58	Unknown
R17	Horvath <i>et al.</i> (2015)	A literature review on challenges and effects of software defined networking	44	2010–2014
R18	Coutinho <i>et al.</i> (2015)	Elasticity in cloud computing: a survey	82	2009–2013
R19	Jula <i>et al.</i> (2014)	Cloud computing service composition: a systematic literature review	34	2009–2013
R20	Latif <i>et al.</i> (2014)	Cloud computing risk assessment: a systematic literature review	31	2009–2013
R21	El-Gazzar (2014)	A literature review on cloud computing adoption issues in enterprises	51	2009–2014
R22	Steninger and Nedbal (2014)	Characteristics of cloud computing in the business context: a systematic literature review	21	2008–2013
R24	Alabool and Mahmood (2014)	Common Trust Criteria for IaaS cloud evaluation and selection	39	1985–2013
R25	Stavru <i>et al.</i> (2013)	Challenges for migrating to the service cloud paradigm: an agile perspective	58	before 2012
R26	Alabool and Mahmood (2013)	Review on cloud service evaluation and selection methods	40	2007-2012
R27	Li <i>et al.</i> (2013)	On evaluating commercial Cloud services: a systematic review	82	2006-2011

(continued)

Table AII. Included systematic reviews

Table All.

Id	Authors/year	Title	No of primary studies	Time-span
R28	Sharma and Maurer (2013)	A roadmap for software engineering for the cloud: results of a systematic review	17	2008-2010
R29	Jamshidi <i>et al.</i> (2013)	Cloud migration research: a systematic review	23	2010-2013
R30	Walterbusch <i>et al.</i> (2013)	Evaluating cloud computing services from a total cost of ownership perspective	Unknown	unknown
R31	Silva <i>et al.</i> (2013)	A systematic review of cloud lock-in solutions	78	Unknown
R32	Da Silva and Lucrédio (2012)	Software engineering for the cloud: a research roadmap	100	2008-2012
R33	Wind <i>et al.</i> (2012)	Towards a cloud computing selection and evaluation environment for very large business applications	Unknown	unknown
R34	Inçki <i>et al.</i> (2012)	A survey of software testing in the cloud	Unknown	2009-2012
R35	Iankoulova and Daneva (2012)	Cloud computing security requirements: a systematic review	55	before 2011
R36	Motta <i>et al.</i> (2012)	Cloud computing: An architectural and technological overview	39	2008-2012
R37	Motta <i>et al.</i> (2012)	Cloud computing: a business and economical perspective	51	2008-2012
R38	Rebollo <i>et al.</i> (2012)	A systematic review of information security governance frameworks in the cloud computing environment	6	2006-unknown
R39	Repschlaeger <i>et al.</i> (2012)	Cloud requirement framework: requirements and evaluation criteria to adopt cloud solutions	Unknown	Unknown
R40	Nasir and Niazi (2011)	Cloud computing adoption assessment model (CAAM)	Unknown	Unknown
R41	Martens and Teuteberg (2011)	Risk and compliance management for cloud computing services: designing a reference model	Unknown	Unknown
R42	Motta and Sfondrini (2011)	Research studies on cloud computing: a systematic literature review	79	2008-2011
R43	Jia <i>et al.</i> (2016)	5W+1H pattern: a perspective of systematic mapping studies and a case study on cloud software testing	51	2010-2012
R44	Abdelmaboud <i>et al.</i> (2015)	Quality of service approaches in cloud computing: a systematic mapping study	67	2008-2012
R45	Cruz Zapata <i>et al.</i> (2015)	Security in cloud computing: a mapping study	344	2009-2012
R46	Alcañiz <i>et al.</i> (2014)	Security in legacy systems migration to the cloud: a systematic mapping study	10	2008-unknown
R47	Neto <i>et al.</i> (2014)	A systematic mapping study on fault management in cloud computing	166	2008-2012
R48	Botto <i>et al.</i> (2014)	Are model-driven techniques used as a means to migrate SOA applications to cloud computing?	48	2006-2013
R50	Sharma <i>et al.</i> (2012)	Testing of web services – a systematic mapping	150	2002-2011
R51	Schneider and Sunyaev (2016)	Determinant factors of cloud-sourcing decisions: reflecting on the IT outsourcing literature in the era of cloud computing	88	Before 2014
R52	Singh and Chana (2016)	A Survey on Resource Scheduling in Cloud Computing: issues and Challenges	110	2009-2015

(continued)

Id	Authors/year	Title	No of primary studies	Time-span
R53	Duan <i>et al.</i> (2015)	Everything as a Service (XaaS) on the Cloud: Origins, Current and Future Trends	100	1984–2014
R54	Pfarr <i>et al.</i> (2014)	Cloud computing data protection – a literature review and analysis	33	2000–2013
R55	Sturm <i>et al.</i> (2014)	Moving in the right direction? Mapping literature on cloud service certifications' outcomes with practitioners' perceptions	42	Unknown
R56	Viseur <i>et al.</i> (2014)	Cloud computing and technological lock-in: literature review	24	Unknown
R57	Barton and Seel (2014)	Business process as a service – status and architecture	16	2006–2014
R58	Baliyan & Kumar, 2014	Towards software engineering paradigm for software as a service	Unknown	Unknown
R59	Fremdt <i>et al.</i> (2013)	Does Cloud Computing matter? An analysis of the cloud model software-as-a-service and its impact on operational agility	28	2007–2011
R60	Hoberg <i>et al.</i> (2012)	The business perspective on cloud computing – a literature review of research on cloud computing	60	Before 2012
R62	Müller <i>et al.</i> (2015)	Benefits of cloud computing: literature review in a maturity model perspective	47	Unknown
R63	Azevedo <i>et al.</i> (2016)	Densifying the sparse cloud simsaas: the need of a synergy among agent-directed simulation, SimSaaS and HLA	Unknown	2004–2015
R64	Yang and Tate (2012)	A descriptive literature review and classification of cloud computing research	205	2008–2011
R65	Repschlaeger <i>et al.</i> (2012)	A reference guide to cloud computing dimensions: infrastructure as a service classification framework	38	unknown
R67	Zhao <i>et al.</i> (2014)	Research gaps and trends in cloud computing: a systematic mapping study	523	2009–2014
R68	Moghaddam <i>et al.</i> (2015)	Energy-efficient networking solutions in cloud-based environments: a systematic literature review	44	2008–2013
R69	Paula and Carneiro (2016)	Cloud computing adoption, cost-benefit relationship and strategies for selecting providers: a systematic review	66	2005–2015
R70	Singh and Chana (2015)	Cloud resource provisioning: survey, status and future research directions	105	2007–2014
R71	Paulsson <i>et al.</i> (2016)	Cloud service brokerage: a systematic literature review using a software development lifecycle	41	2009–2015
R73	Jede and Teuteberg (2016)	Investigating preconditions for a financially advantageous cloud usage	Unknown	Unknown
R74	Milani and Navimipour (2016)	Load balancing mechanisms and techniques in the cloud environments: systematic literature review and future trends	18	2010-2015
R75	Pahl and Jamshidi (2016)	Microservices: a systematic mapping study	21	2014–2015
R76	Priyadarshinee <i>et al.</i> (2016)	Risk analysis in adoption of cloud computing in SMEs – A literature review	55	2010–2014
R77	Leal and Musicante (2015)	Using SLA to guide database transition to NoSQL on the cloud: A systematic mapping study	35	2009–2015

(continued)

Table All.

Id	Authors/year	Title	No of primary studies	Time-span
R78	Slawik (2015)	Cloud service matchmaking approaches: a systematic literature survey	Unknown	Unknown
R79	Lehrig <i>et al.</i> (2015)	Scalability, elasticity and efficiency in cloud computing: a systematic literature review of definitions and metrics	20	2005–2014
R80	Witti <i>et al.</i> (2016)	Security governance in multi-cloud environment: a systematic mapping study	163	Unknown
R81	Brabra <i>et al.</i> (2016)	Semantic web technologies in cloud computing: a systematic literature review	36	2008–2016
R82	Karunakaran <i>et al.</i> (2015)	Business view of cloud: decisions, models and opportunities – a classification and review of research	155	Before 2012
R83	Murad and Dowaji (2016)	Service value optimization of cloud hosted systems using particle swarm technique	35	Unknown
R84	Chana and Rana (2012)	Empirical evaluation of cloud-based testing techniques: a systematic review	82	2003–2012
R85	Hasteer <i>et al.</i> (2013)	Pragmatic assessment of research intensive areas in cloud: a systematic review	36	2009–2012
R86	Hashizume <i>et al.</i> (2013)	An analysis of security issues for cloud computing	15	Unknown
R87	Carvalho <i>et al.</i> (2015)	Can data integration quality be enhanced on multi-cloud using SLA?	114	1998–2014
R88	Haag and Eckhardt (2014)	Organizational cloud service adoption: a scientometric and content-based literature analysis	36	2007–2012
R89	Mazher and Ashraf (2014)	A systematic mapping study on cloud computing security	39	2000–2013
R90	Carvalho <i>et al.</i> (2013)	A systematic mapping study on cloud computing	301	2008–2011
R91	da Silva <i>et al.</i> (2012)	Accounting models for cloud computing a systematic mapping study	23	2011 (July–December)
R92	Andreoc <i>et al.</i> (2012)	Cloud computing ontologies: a systematic review	24	2008–2011
R94	Khatibi and Khatibi (2012)	Issues on cloud computing: a systematic review	Unknown	Unknown
R95	da Silva <i>et al.</i> (2013)	Systematic mapping study on security threats in cloud computing	34	2004–2013
R96	Maartens <i>et al.</i> (2011)	Understanding the cloud computing ecosystem: results from a quantitative content analysis	485	2007–2010
R97	Gholami <i>et al.</i> (2016)	Cloud migration process – a survey, evaluation framework and open challenges	43	2009–2015
R98	Endo <i>et al.</i> (2016)	High availability in clouds: systematic review and research challenges	19	2010–2015
R99	Madni <i>et al.</i> (2016)	Recent advancements in resource allocation techniques for cloud computing environment: a systematic review	159	2008–2016
R100	Alkawsii <i>et al.</i> (2015)	Factors influencing the adoption of cloud computing in SME: a systematic review	22	2011–2014