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Requirement Engineering Challenges: A Systematic Mapping Study on the Academic and the Industrial Perspective

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Abstract
Requirement engineering (RE) is the process of discovering stakeholders' requirements and needs and documenting them in such a way that they can serve as the basis for all other system development activities. Despite recent advances in RE practices and tools, requirements engineers are still experiencing fundamental problems. Therefore, the identification and characterization of such challenges would help RE practitioners manage and overcome such difficulties allowing them to meet expected quality objectives. The main objective of this paper is to identify and compare RE challenges reported in the literature and in practice. To this aim, we have conducted a systematic mapping study to collect and analyze RE challenges in the literature. Furthermore, we have also conducted a questionnaire-based empirical investigation to collect and analyze RE challenges faced by IT practitioners working for 15 companies located in four different countries. Results show that the top challenges are the same in the literature and in practice. However, overall, our comparative study revealed a weak positive correlation between RE challenges in the literature and in practice (Spearman coefficient = 0.3061). This weak positive relationship indicates that some of the challenges found in the literature are not perceived by the participant to have a great impact on the practice. This may be due to the fact that solutions to (or guidelines to avoid) some of the identified challenges have been provided by the surveyed corporations.

Keywords Requirements Engineering (RE) · Challenges · Systematic mapping study · Practice

1 Introduction

Requirement engineering (RE) is the most important phase of the software development life cycle (SDLC) [1]. RE is the process of discovering stakeholders' requirements and needs and documenting them in such a way that they can serve as the basis for all other system development activities [1]. It involves the collection, analysis, documentation, validation, and management of the requirements of the proposed software system, as articulated by the intervening stakeholders [2]. Typical stakeholders include customers, the customers' customers (in case a system is used by third parties), sponsors (in the case the system being built is not for sale), all technical persons (e.g., development, test, maintenance, etc.), regulators (e.g., government agencies), and third parties who have interest in the system. It is worth noting that sometimes the customer is called the client (usually in the case of software systems) [3]. In this paper, the terms 'client' and 'customer' are used interchangeably.

Being a foundation of software development, the RE process is faced with a number of challenges and inherent difficulties related to each of the sub-processes within RE, such as conflicting stakeholders' requirements and goals, the requirements articulation problem, and the requirement change management problem [4]. These challenges and problems have motivated researchers to undertake research in various areas of RE, leading to a large body of research [4–7]. However, over the last couple of decades, despite their success to overcome some of the RE challenges requirements engineers are still experiencing fundamental problems that indicate a need for more effective RE practices and more customized RE tools [8].

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Furthermore, the advent of new technologies in the information and communication technologies (ITC) field, along with the recent trends towards implementing more agility into existing business processes (dictated by the constant adaptation to new socio-organizational contexts), led to the emergence of a new set of RE challenges [9]. Hence, we believe that the definition and classification of RE challenges still represent an open issue that needs to be addressed from both practical and research perspectives. Consequently, an analytical study is required to compare and map challenges defined in the literature to the real-world development context.

In addition, the interest in practical influence of software engineering (SE) research has been growing and the relationship between real practices and research is getting narrower. Researchers have developed, validated, and transferred into practice innovative solutions for several software engineering problems. In order to measure the gap between software engineering research and practices within the software industry, Ivanov et al. [10] conducted an empirical study (within the SE community) and concluded that many of the SE research outcomes are not applied in the industry [10]. In addition, recent studies showed the existence of a gap between what is studied in systematic reviews and real practices within the software industry [11–13].

In an attempt to address the issues discussed above, the purpose of this paper is threefold. First, it presents a systematic mapping study to identify, define, analyze, and classify the main RE challenges available in the literature. Second, it gathers and analyzes RE challenges faced by software practitioners in IT enterprises. The data were collected by means of a questionnaire survey administered to practitioners located in four countries within three continents. Participating practitioners have different levels of experience, and work for enterprises of different sizes. Furthermore, we investigate how the enterprise size and the level of experience affect the type of RE challenges that practitioners are facing. Third, it provides a comparative analysis of RE challenges collected from literature versus those identified by practitioners.

Many studies attempted to survey RE challenges in the literature [5–7,14], while others used case study to collect RE challenges in IT industries [15–19], and yet few others used questionnaires to collect RE challenges faced by practitioners [20–22]. However, to the best of our knowledge, none of the existing studies combined the following three contributions:

1. A mapping study that provides an in-depth review and a classification of RE challenges based on common RE activities, e.g., feasibility study, elicitation, specification, and validation.
2. A collection and an analysis of RE challenges faced by software practitioners with respect to organizations size and the proficiency of software practitioners.
3. Conducting a comparative analysis of the RE challenges faced in both worlds, academia and industry.

Furthermore, and contrary to the studies that have focused on RE challenges related to a specific process, e.g. agile development [23–25], or to a specific domain, e.g., automotive [26], market-driven software development [21], we opted for a general approach that includes all existing software development processes and covers different product domains.

The remainder of this paper is structured as follows. Related work is summarized in Sect. 2. Section 3 describes the research methodology. Section 4 presents a qualitative and quantitative analysis of the challenges identified during the mapping study. Section 6 presents questionnaire survey findings. A comparison of the data collected from the mapping study and the one collected from the questionnaire is presented in Sect. 7. Section 8 discusses the threats to validity. Finally, conclusions and future work are presented in Sect. 9.

2 Related Work

Several studies attempted to identify RE challenges and analyze them. These studies can be classified, according to the methodology they adopt, into three categories:

1. Survey the literature to identify the RE challenges [5–7,14,27–31].
2. Collect RE challenges using questionnaires and interviews [5,20–22,32–34,34,35].
3. Identify RE challenges through the use of case studies [15–19].

2.1 Literature Surveys to Identify RE Challenges

Besrour et al. [5] conducted a systematic literature review (SLR) on requirements engineering challenges within small and medium software enterprise, spanning a period of two decades, i.e., from 1995 to 2016. The authors [5] identified a total of 24 RE challenges, out of which 12 were classified as critical.

Researchers have also conducted empirical studies to investigate and identify RE challenges relative to specific domains of software engineering. Bano and Ikram [6] studied RE challenges and issues in Service-Oriented Software Development (SOSD). Two SOSD RE perspectives were considered, service provider and service requester. Challenges were classified based on these two perspectives, into 4 categories, namely specification issues, service discovery issues, knowledge management issues, and composition issues. A total of 15 SOSD RE challenges were identified, seven of them were inherited from component-based

software development (CBSD). Among the most important challenges, we find 'difficulty to located correct service according to user requirements' and 'redesign and redeploy the composed service when user needs change.'

In Kauppinen et al. [27], the authors identified some critical challenges that typically affect the execution of a RE process within an organization. The study showed that factors, such as the definition of the RE process scope, providing adequate training and support resources, reducing the duration of execution of a new RE process, and defining proper process measurement tools, are among the most important RE challenges in the IT industry.

Ashgar and Umar [7] conducted a literature review to investigate RE challenges faced during the development of Customer off-the shelf (COTS) software. The resulting challenges were categorized into seven classes, namely technology, time, stakeholders, organization, economic crises, RE process, and external events. Among the major RE challenges, Ashgar and Umar [7] listed the modeling and classification of extensive data, inconsistent and incomplete description of the process, and validation and verification of requirements.

Given their important societal impact, their evolutionary nature, and the complexity of operational environment of large-scale systems of systems, Cornelius Ncube [28] identified some RE challenges and proposed some activities to address them. Cornelius Ncube emphasized challenges related to handling competing stakeholder demands, weaving interoperable systems-of-systems, persistent interoperable architecture, dynamic evolution of systems-of-systems, and how emergent behaviors impact the stability of requirements.

Ambiguity in Natural Language (NL) requirements have long been acknowledged as an unavoidable challenge in RE. Many studies have been conducted by RE researchers to tackle this challenge. Muneera Bano [29] conducted a mapping study in order to study ambiguities in natural language requirements. The study focused on the application of Natural Language Processing (NLP) techniques and tools for addressing ambiguity in requirements. Three main categories of NL ambiguity can be distinguished, syntactic, semantic and lexical. A total of 28 empirical studies were selected, out of which 16 studied syntactic ambiguities, 5 studied semantic ambiguities, and 4 studied lexical ambiguities. Out of the 28 studies, 23 focused on detection of ambiguity, while 9 addressed the reduction or the removal of ambiguities.

Requirements change is one of the most important challenges for any requirements engineering process. The failure or success of a software development project is greatly determined by the ability to cope with requirements changes. Bano et al. [30] conducted an SLR on the causes of requirements changes. Surprisingly, only five papers were selected (from a large pool of papers). The extracted causes of requirements changes are then classified into two major types, i.e., essential (change in organizations' policy) and accidental causes (such as vague production strategy). However, in order to confirm their findings, additional evidence in support of this categorization is required. Moreover, since the identified causes of requirements change were at different levels of abstraction, conclusions couldn't be drawn.

To identify the strengths and the weaknesses of available elicitation techniques based on the challenges faced by requirements engineers, Okesola et al. [14] studied the challenges faced by requirements engineering during requirements elicitation. Eight requirements elicitation methods (Workshops, Brainstorming, Joint application development (JAD), Prototyping, Ethnography, Group work, User scenarios, and Introspection) were studied and classified in three categories, individual, contextual, and collaborative. In order to compare requirements elicitation methods, the authors [14] used two criteria: (1) the quality of feedback, which includes Proximity to use (PTU), Effort per user (EPU), and Required skills (SKI), and (2) the terms of the collection of information, which include Structure (STR), Richness (RIC), and Quantifiability (QUA).

Requirements inconsistency is recognized as a critical RE challenge. Spanoudakis and Zisman [31] conducted a survey to investigate RE inconsistency detection and resolution methods and tools. The research is structured according to a theoretical framework that views inconsistency management as a process composed of six activities, namely (1) identification of overlaps, (2) detection of inconsistencies, (3) diagnosing inconsistencies, (4) handling inconsistencies, (5) tracking inconsistencies, and (6) putting in place proper inconsistencies management policies.

2.2 Use of Questionnaires/Interviews to Collect RE Challenges

Many studies attempted to identify challenges of requirements engineering by collecting information from software engineering practitioners using questionnaires and interviews [5,20–22,32–34,34,35].

Karlsson et al. [21] conducted an empirical study to identify RE challenges in market-driven software development. The data were collected using a qualitative approach by interviewing fourteen practitioners from eight different Swedish software corporations and through a focus group meeting with practitioners. The study identified a total of 12 challenges, 5 of which are specific to market-driven organizations, such as the communication gap between marketing staff and developers, and release planning based on uncertain estimates. The reported challenges were tailored to the market-driven software development process; therefore, they cannot be generalized as the faced challenges may not be the same in other types of software development processes, e.g., agile, RUP, etc. In addition, a small number of practitioners

(14 participants), and companies (8 Swedish corporations) participated in the study, making the generalization of results difficult.

Birk and Heller [32] conducted a qualitative study to collect challenges faced during the requirements engineering of software product line (SPL) products. The RE challenges were derived from several discussions with software product line experts from more than fifteen software companies. The study reveals that SPL requirements are considerably harder than requirements for single-product development mainly because of (1) the use of two-stage RE phase, i.e., product and platform, (2) dealing with many variants of the product, (3) long-living requirements, (4) many different stakeholders, (5) Change management of requirements, (6) Versions and variants of requirements, and (7) the difficulty to establish tool support. Authors [32] did not provide the details of the qualitative process, e.g., number of SPL experts who participated in the study, the interview questions, results, etc.

Liu et al. [20] conducted a questionnaire survey to identify the major reasons of failure in requirements engineering practices, particularly, requirements elicitation approaches and requirements representation techniques. The survey was conducted in 2009 and targeted three types of Chinese software development companies: (1) multi-national corporations, (2) government owned enterprises, and (3) domestic private companies. Furthermore, the survey targeted two different product types, mass marketed software products, and outsourcing products. The study identified eight major failure reasons in RE practices and proposed some improvements to overcome them. However, the study neither ranked the obtained challenges (by criticality or importance) nor analyzed them.

Sabaliauskaite et al. [33] studied the existing challenges in aligning the requirements and verification processes. In their qualitative study, the authors [33] interviewed 11 professionals in a large software development company in Sweden. The involved participants do not work directly with artifacts, but with processes and have expertise in fields like requirements, testing, quality, and measurement. A conceptual model (showing three dimensions of requirements and test artifacts, connected through work processes), was using during the interviews as a guide. The study reported five challenges related to the company's organizational structure and processes, two challenges related to people, five challenges related to tools, five challenges related to the requirements process, five challenges related to the testing process, three challenges related to change management, four challenges related to traceability, and four challenges related to measurements. Since the study is conducted in one single corporation, its results cannot be generalized.

Sahibzada and Zowghi [34] conducted an online survey in order to validate the list of Service-Oriented RE (SORE) challenges, identified in Bano and Ikram [6], from practitioners' perspectives. A total of 117 responses were collected and analyzed resulting in the following top five challenges related to: (1) alignment of Business Requirements (BRs) and services, (2) integration of Knowledge Management (KM) strategy to Service-Oriented Software Development (SOSD) life cycle, (3) iterative service discovery process, (4) Non-functional requirements, and (5) Requirements change management. Later, Bano et al. [35] conducted another qualitative research using series of interviews. The data were collected by conducting 14 interviews with practitioners working in IT companies in Sydney. The study confirmed the five top ranked SORE challenges reported in [34]. The authors findings reveal that most of the SORE challenges are similar to those that are faced during RE in traditional or component-based software development.

Soltani and Knauss [22,36] identified RE challenges in the context of AUTomotive Open System Architecture (AUTOSAR) ecosystem. The objective of AUTOSAR is to enable the reuse of software components as well as their interoperability in the automotive sector. The authors [22] interviewed 7 project managers from an AUTOSAR-Tier-2 supplier, and triangulated their results with 6 additional interviews with subjects from two Tier-1 suppliers and one OEM (original equipment manufacturer). The results of the interviews show that the most popular RE challenges in the context of AUTOSAR ecosystem were related to nonstandard requirements. The reported challenges include distant communication, in which it would take a long time to reach the owner of the requirement (due to the fact that the OEM and Tier-1 suppliers are big companies that are geographically dispersed). Cultural difference is also one of the reported challenges, in which stakeholders with no expertise in software often struggle in accepting the need for progressive and incremental clarification of requirements. This is due to the multidisciplinary nature of automotive engineering, in which experts come together from different backgrounds, such as software, electrical, and physics.

In addition to the conducted SLR, Besrour et al. [5] have performed an empirical study using a questionnaire to collect challenges from practitioners working for Malaysian software SMEs. Respondents were classified according to their gender, position in the enterprise, and number of years of experience. The collected data were analyzed using descriptive statistics and frequency analysis. In our research, we collect RE challenges faced by practitioners working for SMEs and also for large enterprises.

In Fernandez et al. [37], the authors launched an initiative, called Naming the Pain in Requirements Engineering (NaPiRE), that aims to report on the status quo and problems in practical RE. The authors used 21 RE problems to design their questionnaire paying special attention to the accuracy, validity, transparency, openness, and anonymity of the collected data. The survey data were collected from

228 organizations in various domains across 10 different countries. A cause–effect analysis was conducted in order to understand how the most critical RE problems manifest themselves in practical environments. It is worth noting that the 21 used RE challenges were derived ad hoc from the literature. Furthermore, no additional challenges were identified from practitioners.

In Solemon et al. [38], the authors conducted a study to investigate RE challenges and problems in the Malaysian IT industries. The study was performed via self-administered questionnaire involving 500 sampled IT companies across Malaysia. The identified RE problems were classified into organizational-based and RE process-based. The authors claimed that high maturity practices do not necessary correlate with better performance. Moreover, the researchers compared their questionnaire findings with three similar studies reported in the literature.

2.3 Use of Case Studies to Collect RE Challenges

Rajnell et al. [15] described an industrial case study in which a RE prioritization process was proposed, observed and evaluated, in the context of market-driven development. The case study is composed of 17 feature groups with a total of 58 features to be prioritized. The participating 10 stakeholders were asked to prioritize both the feature groups and the features. Each prioritization was carried out through the distribution of a predefined amount of fictitious money ($100,000). Feedback was collected through a questionnaire. The study revealed three main RE prioritization challenges: (1) difficulties with absolute assessment, (2) assessment of prioritization quality, and (3) sensitivity to 'shrewd tactics' (e.g., stakeholder gives an extra-low priority to a feature knowing that other stakeholders will give it high priority, in order to serve his purpose). However, the fundamental problem with this study is that stakeholders are representatives from marketing who may not know how a specific necessity ought to be translated or how vital it is for the potential clients of their market.

Callele et al. [16] conducted an exploratory case study to investigate the correspondence between RE practices and the development of appropriate mitigation strategies for public policies. The study used North American mainstream media (MSM) press (e.g., news feed such as Google News) to gather materials relative to eight important topics that present public policy issues. The study showed many of the classic RE problems like the existence of significant evidence of unintentional consequences due to inadequate domain knowledge, stakeholder's engagement and identification, problems scoping and terminology definitions. Nevertheless, the authors claimed that RE procedures could be used to support public policy formation and execution. Contrary to our work, the authors [16] did not conduct a comparison between the challenges found in the literature and the RE challenges experienced by practitioners. Instead, they have only indicated that RE challenges are associated with public policies challenges. In addition, the authors [16] did neither quantitatively nor qualitatively analyze the RE challenges and categorize them according to the different RE phases.

In recent years, the globalization of software development received increased attention from the software development community. However, global software engineering brought a new set of challenges impacting requirements engineering activities. Bhat et al. [17] used many case studies from an Indian IT-services firm to provide insights into the root causes of RE phase conflicts in client-vendor off-shore outsourcing relationships. A total of nine RE challenges were reported, namely conflicting client-vendor goals, low client involvement, conflicting RE approaches, misalignment of client commitment with project goals, disagreements in tool selection, communication issues, disowning responsibility, sign-off issues, and tools misaligned with expectations.

The increase in the complexity of software products and the vast growth of software development companies led to a number of new challenges in scaling and implementing RE practices. Wnuk et al. [18] analyzed RE challenges reported from three projects conducted at three companies (2 operating in the development of embedded devices and one in the domain of medical care) of different sizes. The projects duration vary from less than one year to 2–6 years. Thirteen practitioners working on these project were interviewed. The study revealed that the structure of the RE artifacts and scoping are the two main problems facing the scaling of the RE process. The main limitations of this research are the limited number of companies in the study and the small number of interviewed practitioners. Therefore, the reported challenges cannot be generalized without additional case studies.

Hiisila et al. [19] conducted a case study to investigate the challenges faced by customers in outsourced development environments. The case study was conducted in a Finnish insurance company that specializes in statutory pension security and involves the analysis of 15 large projects. A total of seventeen interviews were conducted. The study identified 43 challenges that were categorized into seven categories according to: (1) human resources, organizational capabilities and knowledge, (2) business development and IT as whole, (3) decision-making processes, (4) sourcing model, (5) type of solution, (6) distributed RE process between customer and suppliers, and (7) IT environment, enterprise architecture and development portfolio. The authors [34] claimed that the second and the sixth categories are the most critical ones. Unlike, their approach [19] that is based on interviews, documents reviews, and validation workshops, our approach is based on a systematic mapping study and the use of a questionnaire for validation. Moreover, the challenges that we have identified in the systematic mapping

study were further analyzed and classified based on RE activities. In addition, the challenges we collected from the practitioners were further analyzed based on the proficiency of practitioners and the size of the organization they work for. Furthermore, the authors [19] did not perform any comparison between the challenges discussed in the literature and the ones identified from practitioners.

Kasauli et al. [39] conducted a multiple case studies with 7 large-scale software industries, outlining their challenges related to RE in large-scale agile software development, together with best practices from industries. All 7 selected case studies represent large, global industries developing systems and products that involve a large volume of software, hardware, and typically mechanical components. The authors also analyze the literature about 2 common large-scale agile methods, LeSS and SAFe, to obtain possible solutions for the challenges. The outcomes of their work are based on 20 interviews, 5 focus groups, and 8 cross company workshops which they utilized to both gather and evaluate their results. The authors identify 24 RE challenges which they grouped in to 6 categories, then mapped to solutions from LeSS, SAFe, and their companies, when available. However, unlike our research that is not content specific, their work is specifically for agile software development process.

3 Research Methodology

In order to address the three research questions stated in Sect. 3.1, our methodology consists of the following three steps:

1. **Conduct a mapping study**
   - A mapping study is performed with the aim to identify RE challenges discussed in the literature.
   - Summarize, define, and justify the RE challenges identified from the literature.
   - Quantitatively/qualitatively analyze and categorize the collected RE challenges according to the different RE phases.
2. **Conduct a survey within IT practitioners**
   - Conduct an empirical study using a questionnaire to identify RE challenges faced by practitioners in the IT industry. The data are collected from 23 respondents who are working in fifteen different IT companies within four countries, namely Saudi Arabia, Russia, UK, and Nigeria.
   - Analyze and classify the collected challenges.
   - Study potential correlation between the identified RE challenges and the experience of practitioners.
   - Study potential correlation between the identified RE challenges and the size of companies.
3. **Analyze the findings from the mapping study and the questionnaire data**
   - Compare and contrast between RE Challenges identified in academia and the ones faced by IT practitioners.

3.1 Research Questions

The main goal of this study is to get an insight on requirements engineering challenges reported in the literature and contrast them with those reported by software practitioners. We attempt to address the following research questions:

1. **RQ1**: What are the RE challenges identified in the literature?
   Rationale RE challenges are obstacles faced during the first stages of software engineering development life cycle, which may not have viable solutions using current processes and tools. Hence, the identification of such challenges is a necessary first step in overcoming some of the arising difficulties.
   In order to address RQ1, we aim to conduct a mapping study [40].
2. **RQ2**: What are the RE challenges identified by practitioners in the IT industry?
   Rationale The identification of RE challenges faced within the IT industry is not straightforward and is open to debate as different practitioners, part of different organizations, may have different criteria, beliefs, and perceptions of the RE process.
   RQ2 is addressed by conducting an empirical study using a questionnaire, that is administered to practitioners from the IT industry.
   In addition, we aim to address the following two sub-research questions:
   - **RQ2.1**: Does practitioners experience have an impact on the type of RE challenges they are facing?
     Rationale The identification of RE challenges is based on practitioner's personal observation, perception, and experience. Hence, it is very useful to compare the types of RE challenges practitioners (experienced and less experienced) encounter in practice.
     We aim to address RQ2.1 by conducting a statistical analysis of responses collected from our respondents based on their number of years of experience.
   - **RQ2.2**: Does the company size matter when it comes to the type of RE challenges faced by practitioners?
     Rationale The company size may be considered as

an important factor in dealing with the RE process. Large enterprises tend to have complex structures and processes compared to small ones. In addition, small to medium enterprises (SMEs) normally engage in small to medium size projects. They usually need simpler, more people–focused forms of project management. However, given the limited resources, essential aspects of requirements engineering may be neglected. Furthermore, engaging someone with insufficient knowledge about requirements engineering to lead the development process, may have an impact on the number and types of RE challenges the organization will face.
We aim to address RQ2.2 by conducting a statistical analysis of responses collected from our respondents based on their companies' sizes.

3. **RQ3**: Are there differences between RE challenges identified in the literature and the ones identified by practitioners?
Rationale Having a gap between research and practice may lead to a confusion on which RE challenges are more crucial to tackle, e.g. using improved processes, tools, etc.
We aim to address RQ3 by performing a statistical analysis of both retrieved datasets, i.e., literature and questionnaire data.

4 Analysis of the Challenges Identified During the Mapping Study

The following subsections discuss a qualitative and quantitative analysis of the challenges identified during the mapping study.

4.1 Systematic Mapping Study

In order to identify, evaluate and interpret the available literature relevant to RE challenges, we conducted a mapping study. We have followed the phases described by Petersen et al. [40]. First, a search for relevant publications was performed (paper screening was conducted using inclusion and exclusion criteria), second we have created a RE challenge definition schema that is composed of (1) the name of RE challenge (as commonly referred to in the literature), (2) definition of the RE challenge, and (3) a justification (describing why this is a potential challenge), and third, the publications were mapped.

4.2 Search Strategy

The search for relevant publications was conducted in four main steps:

1. *Search execution* In this study, we have used a keyword search query to retrieve dataset from the following electronic databases: ACM, Citeseer, Elsevier, IEEE Explore, IET, ScienceDirect, Scopus, Springer, Wiley, and World Scientific. Google Scholar is excluded because its content is an aggregation from several databases including but not limited to the aforementioned electronic databases. The search execution has been conducted using the following keyword search query:
"Requirements Engineering" AND (challenges OR issues OR problems OR risks)
Only journal, conference/workshop papers were retained. This step resulted in 20,786 papers. Figure 1 shows the distribution of initial primary studies per library.
2. *Automatic search restrictions* In this phase, the search in all the digital libraries was restricted to the period between 2000 and 2020. In addition to the search by period, other restrictions were applied according to the alternative options available in each digital library. The automated search was further restricted based on abstract, title, keywords, subject area, or combination of two or more features as reported in Table 1, showing the number of studies retrieved in each digital library after applying these restrictions. In total, 1708 studies were retrieved.
3. *Paper screening* Dataset collected from the keyword search query was screened based on exclusion and inclusion criteria. Excluded papers are non-English papers, duplicate papers, white papers, and papers that have irrelevant titles. Included papers are academic research articles that include journals, conference papers and workshops having relevant titles. This phase resulted in 328 papers.
4. *Filtering based on abstracts and full text* The results of previous phases were further filtered based on the paper abstract and full text. Papers that merely mention RE challenges in general but do not actively discuss them, that is papers that are not focusing explicitly on RE challenges, are removed as well. Finally, the 68 most relevant papers were retained. However, two additional papers were found via backward referencing and, hence, have been added, resulting into a total of 70 papers. Table 2 lists the publication venues of the selected papers. Figure 2 shows papers distribution over the last 20-year period, while Fig 3 shows the publication types of the retained papers.

Three main grounded theory approaches were discussed in the literature: Constructivist (Charmaz [41]), Systematic

Table 1 Number of papers identified in the restricted electronic search

Sources	Search applied on	Retrieved
IEEEXplore	Abstract and date	917
ACM	Title and date	262
Scopus	Title and date	186
Citeseer	Abstract and date	142
IET	Title and date	83
Springer	Subject area (Software engineering/ Programming & operating systems) and date	42
Elsevier	Subject area (Computer science) and date	35
Wiley	Abstract and date	15
World scientific	Abstract and date	15
Science direct	Title, abstract and keywords, and date	11
Total		1708

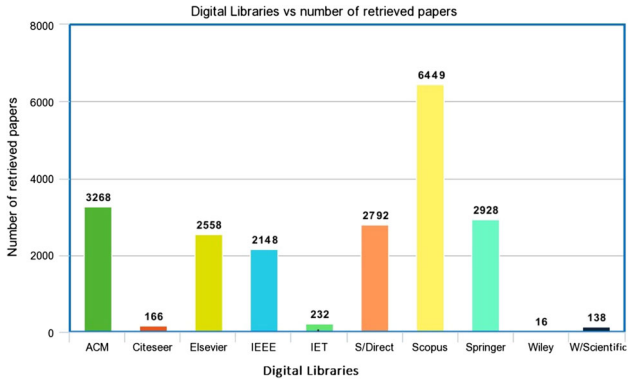

Fig. 1 The distribution of the initial list of studies per library

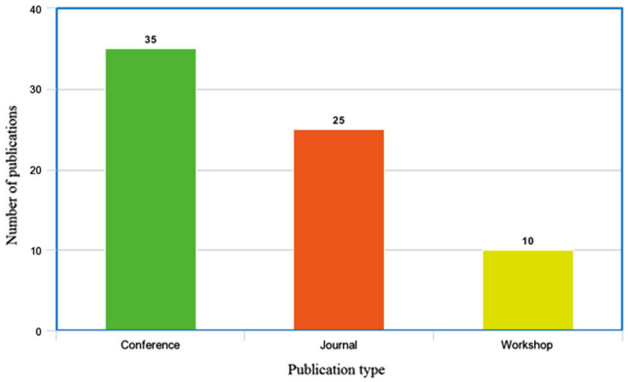

Fig. 3 Publication type of the selected papers

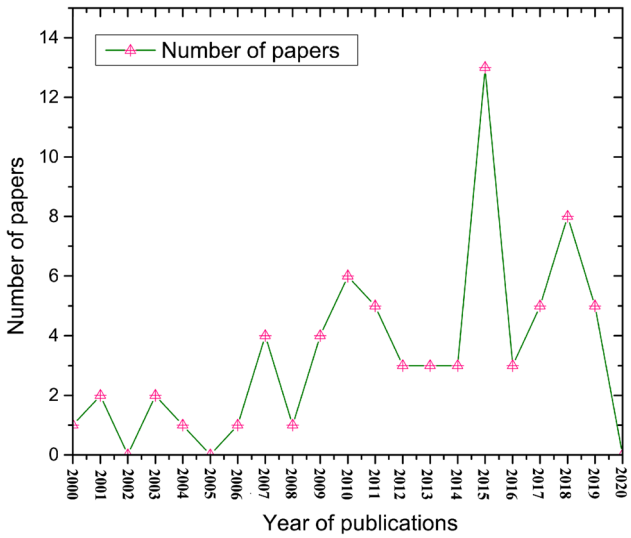

Fig. 2 The distribution of studies over the years

(Corbin and Strauss [42]), and classical/emergent (Glaser [43]). In our context, in order to analyze the 70 retained papers, we have selected the Constructivist approach as it combines both the Systematic [42] and the classical/emergent [43] methods. In Constructivist grounded theory [41], three major strategies for data collection can be used, namely interview, observation, and document/artifact collection. For our study, we have selected the later as we are collecting data from published articles. Furthermore, we have closely followed the Constructivist process to data analysis. The process involves (1) initial coding (examining the meaning each RE challenge from each paper as well as assigning labels to the identified challenges), (2) focused coding (reducing the number of labeled challenges by creating an abstraction of the concept and identifying their inter-connections) and, (3) theoretical coding (coming up with the final RE challenges categories by merging similar challenges as well as consolidating their definitions using our own words.

By following this procedure, first, we have identified, named, classified, defined 52 RE challenges, and computed their recurrences. Two co-authors of this paper cautiously assessed each challenge to reduce any personal bias and to improve the authenticity of the identified challenges. Next, to avoid duplication, similar challenges were merged. Hence, the resulting 52 challenges were reduced to 27 main challenges.

Table 2 Publication venue of the selected papers

#	Venue	# of publications
1	Requirements engineering	5
2	Information and software technology	4
3	IEEE software	3
4	IET software	1
5	Advanced information systems engineering	1
6	ARPN journal of engineering and applied sciences	1
7	Computers in human behavior	1
8	Information systems journal	1
9	IJATS	1
10	International journal of computer applications	1
11	International journal of software engineering	1
12	Journal of cleaner production	1
13	Journal of systems & software	1
14	Procedia computer science	1
15	Software engineering and extreme programming	1
16	Software engineering and knowledge engineering	1
17	EmpiRE	5
18	Scientific workshop proceedings of the XP	2
19	RE4SuSy	1
20	REW	1
21	Workshop on agile requirements engineering	1
22	Conference publications	35

4.3 Collected Challenges

The challenges are documented according to our schema, and mapped as follows:

1. **Lack of clear understanding of system requirements by customer:**
   - *Definition* Some customers do not have a clear understanding of system requirements themselves, including system scope, key functional and non-functional requirements. [5,6,19,20,23–26,34,36,44–60].
   - *Justification (Why)* In most cases, customers provide only the system goals to the software engineer, and do not have a clear understanding of the actual requirements that refine their goal. This usually makes it difficult for the software engineers to come up with a solution that meets the customer needs.
2. **Requirements change and evolution:**
   - *Definition* Clients/customers requirements and understanding keep changing [2,5–7,14,19–21,23,30,34,45,47,48,53,61–71,71–76].
   - *Justification (Why)* Change in software development is inevitable and difficult to control. Clients may mistakenly fail to provide the right requirements at the beginning, which will lead to frequent requirements changes. Also a client may change his mind over time, with regard to a particular requirement due to changes in business, technology, context, or market competition.
3. **Lack of sufficient domain knowledge and expertise by software engineers:**
   - *Definition* In some cases, the software engineer may lack the required domain knowledge necessary to understand the technical requirements [5,7,14,16,18–20,24,26,34,47,52–54,56,57,59,63,66,67,69,72,74,76,77].
   - *Justification (Why)* Mostly, requirements engineers who lack a domain knowledge cannot validate the requirements specifications, hence leading to poor design choices.
4. **Tight project schedule (short development period):**
   - *Definition* A project with a short development time is prone to insufficient understanding of the requirements since there is no enough time for sufficient interactions between the development team and customers [7,20,36,47,48,52,55,58,60–62,71,73,74,76,78].

- *Justification (Why)* As organizations face increasing competition, reducing time-to-market is becoming a key factor to gain market share. This would lead to tight development schedules.

5. **Reuse of an existing design in the wrong context and environment:**
   - *Definition* Organizations wrongly reuse past documented software designs in current projects without taking into consideration the context and environment of the new system [2,6,18–20,23,74].
   - *Justification (Why)* Reuse of an existing design in the wrong context is prone to design flaws and errors.
6. **Poor communication link:**
   - *Definition* Communication gap between requirements engineers and stakeholders during requirement gathering lead to poor requirements quality [5,20–24,26,36,47,58–60,62,63,65,66,68,71–74,76,77,79,80].
   - *Justification (Why)* Due to poor communication link, it may take a long period of time for a requirement engineer to reach out to the client in order to obtain requirements clarifications.
7. **Cultural differences:**
   - *Definition* Although cultural differences and different backgrounds brings diversity among team members, it may cause many conflicts value conflicts. Hence, it presents a significant challenge to successful requirements engineering [14,16,19,22,26,47,59,64,79,81,82].
   - *Justification (Why)* Risks derived from the interaction among team members with different cultural backgrounds can create conflicts that are hard to resolve.
8. **Requirements ambiguities and inconsistencies:**
   - *Definition* A single reader can interpret a requirement in more than one way or several readers can interpret a requirement differently from one another [5,18,21,22,29,34,36,47,48,59,62,69,74].
   - *Justification (Why)* When software engineers have to make assumptions about ambiguous requirements, they are entitled to (and will) interpret requirements in the way most favorable to them. This may lead to the development of systems that are not fit-for-purpose.
9. **Long feedback cycles to verify the requirements:**
   - *Definition* Taking a long time to receive feedback from the requirements owner [14,22,23,25,26,34,44,52–57,66,71,73,75,79].
   - *Justification (Why)* Delayed feedback from the client would have delay requirements verification, which may result in missing key deadlines.
10. **Poor identification of stakeholders:**
    - **Definition**: Inability/failure to identify stakeholders and their roles [5,6,15,16,19,23,24,26,31,47,49,50,59,66,72,79].
    - **Justification (Why)**: For a project to become successful, a project manager must identify roles of each stakeholder and develop a good relationship with them.
11. **Lack of ensuring stakeholders' satisfaction of the requirements:**
    - *Definition* Failure to meet the stakeholders' needs and expectations [5,18,19,23,24,51,53,58,60,66,71,74,79].
    - *Justification (Why)* Project will be unsuccessful if the end product fails to satisfy stakeholders' needs.
12. **Poor modeling of functional requirements:**
    - *Definition* Failure to provide proper models of functional requirements during the requirements gathering and analysis phase [5,74].
    - *Justification (Why)* Poor modeling of functional requirements may lead to system bugs and defects.
13. **Poor requirements traceability and interdependencies:**
    - **Definition**: Failure to define relationships between stakeholders and requirements [5,19,21,23–26,44,47–49,53,59,64,66,68,72,74,75].
    - **Justification (Why)**: It may be difficult to maintain projects with bad requirements traceability and interdependencies.
14. **Poorly defined specifications:**
    - *Definition* Failure to provide well-defined specs during the phase of a requirement specification [5,23,48,53,71,74].
    - *Justification (Why)* Poorly defined specifications may lead to system anomalies and inconsistencies.
15. **Failure to prioritize requirements:**
    - **Definition**: Requirement engineers fail to rank requirements based on their criticality, importance, return on investment, cost of delay, etc. [5,48,49,51–54,56,57,61,71,74,75,79].
    - **Justification (Why)**: A project may not be completed within its stipulated time frame due to poor requirements prioritization.

16. **Incomplete requirements:**
    - *Definition* Incomplete requirements means missing information in the process of requirements gathering [5,14,23,25,32,34,45,47,48,51–55,58,66,69,71,73–77].
    - *Justification (Why)* Missing requirements information may lead to inability to implement the required system features.
17. **Poor requirements risk management:**
    - *Definition* Failure to identify, document, and address potential project risks during the RE process [5,7].
    - *Justification (Why)* Inability to carefully manage potential requirements risks may lead to project failure.
18. **Difficulties in formalizing requirements from natural language:**
    - *Definition* Difficulties to transform requirements expressed in natural language into a structured formal form [6,23].
    - *Justification (Why)* Formalization of natural language requirements would reduce ambiguities and would allow for formal validation and verification.
19. **Conflict detection and resolution:**
    - *Definition* The challenges faced in resolving a conflict between stakeholders during requirements elicitation and analysis [6,14,19,25,31,32,36,47,48,64,65,69,74,79,80].
    - *Justification (Why)* Stakeholders' conflicting views may affect the progress of the project.
20. **Requirements analysis challenge:**
    - *Definition* The difficulties encountered during requirements analysis [23,34,61,68,74].
    - *Justification (Why)* There are many difficulties associated with the analysis of different requirements artifacts (e.g., goal models, use cases, flowcharts, NFR, etc.) such as checking the compliance with the used formalism.
21. **Difficulty in selecting suitable metrics:**
    - *Definition* One of the main RE challenges is acquiring and selecting the appropriate type of RE metrics. It requires prior knowledge about the different RE metrics to choose the most suitable one to the requirements domain [68,74,79].
    - *Justification (Why)* There are many types of available metrics. Deciding which one to use is an important step which has a great impact on the RE process.
22. **Difficulty in implementing and improving RE within the organization:**
    - *Definition* There are many difficulties that an organization may face while implementing a new RE process or improving an existing one. These difficulties include, among others, challenges related to (1) the readiness of the organization for adopting a new RE process (e.g., structural organization), (2) the required training that the staff needed, and to (3) the time taken to implement a new RE process [21,74]:
    - *Justification (Why)* From a practical perspective, RE activities are not usually handled by RE experts. Therefore, the execution or the improvement of a RE process within an organization may be very challenging.
23. **Abstaining from allocating resources to RE:**
    - *Definition* Not considering RE activities when planning the project budget [19,21,26,32,34,48,51,61,63,72,74,76,77,83].
    - *Justification (Why)* Some organizations prefer not to allocate resources for requirements engineering in order to minimize cost.
24. **Organizational instability:**
    - *Definition* Corporations with frequent restructuring activities, lack of organizational support for employees, short planning window, etc. [19,21,47].
    - *Justification (Why)* Employees working for unstable organizations tend to quit their jobs and look for stable corporations.
25. **Poor compliance with standard RE processes:**
    - *Definition* Abstaining from following RE process guidelines [7,21,23,34,58–60,65,74,77,83].
    - *Justification (Why)* It will be difficult to successfully collect and analyze the requirements of a complex system without following standard RE process guidelines.
26. **Estimate uncertainties (release planning based on uncertain estimates):**
    - *Definition* Documenting plans with assumed variable depreciation, taxes, etc. [7,16,19,21,23,25,34,36,47,51,52,54,65,69,71,73,76].
    - *Justification (Why)* Uncertain estimates will affect the cost and scope of a project.

27. **Change in technology:**
    - *Definition* Technological advances may lead to the introduction of new requirements, new RE tools, etc. [7,35,51].
    - *Justification (Why)* RE techniques should be updated to keep up with technological changes, otherwise, they will become obsolete.

4.4 Collecting Challenges from IT Practitioners

It is important to note that 4 out of 27 challenges identified from the literature that include more than one phrase were further subdivided into two phrases and considered as separate challenges while preparing the questionnaire in order to have clear responses from the participants. A closed format questionnaire [1] was designed and used as an instrument to collect data from practitioners. It was developed using the Google Forms application, which is available online. We decided to use the online questionnaire due to its added advantage of storing responses in an Excel sheet for later analysis and reference. Invitations to participants were sent via different means, ranging from personal contacts to emails found via companies' website. Next, emails with a link to the web-based survey were sent to participants who agreed to participate in our research study. The profiles of these participants varied, ranging from system analysts to project managers across the broad software development companies.

4.5 Comparison of Challenges Collected from the Mapping Study and from IT Questionnaire

The RE challenges collected during the mapping study will be analyzed against the challenges collected from IT practitioners. We applied Spearman's [84] rank-order method to measure the significance of the resemblance in the challenges found from the literature and the questionnaire survey.

5 Analysis of the Data Collected from the Mapping Study

In what follows, we analyze the data collected from the mapping study.

5.1 Recurrence of RE Challenges

In light of the challenges collected as part of the mapping study, we used the recurrence investigation strategy to compute a score for each challenge. The number of events and percentages of every datum variable would then be reported using a recurrence table. Frequencies are useful for analyzing and comparing the collected data and can be utilized for both ordinal/nominal or numeric information. To analyze the recognized challenges, the event of challenges in each paper was tallied. Lastly, the overall significance of each test was distinguished by looking at the events of one challenge against the event of alternate challenges.

Table 3 lists the RE challenges identified from the literature with their corresponding frequencies and percentages. 'Requirements change and evolution' (46%) is identified as the most common challenge. Changes in requirements are inevitable and difficult to control as the client requirements may evolve over time due to various reasons, e.g., changes in business, technology, context, and regulations. Moreover, trying to enhance the understanding of requirements would lead to changes, updates, and even the definition of new requirements.

The 'Lack of clear understanding of system requirements by customer' is recorded as the second most frequent challenge (39%). This is expected considering the roles of customers in defining requirements. However, in most cases, customers provide only the system goal to the software engineer and do not care about the detailed requirements that will make up that goal. This usually makes it difficult for the software engineers to come up with a solution that meets the customer needs. The third most common challenge is 'Lack of sufficient domain knowledge and expertise by software engineers' (36%). This can be justified considering the fact that it is always difficult for the requirements engineer who lacks a domain knowledge of the proposed system to predict the feasibility of the system or figure out when the system requirements are incorrect. 'Poor communication link' (36%) is ranked in the third position as well. This is justifiable because, with a bad communication link, it may take a long period of time for a requirements engineer to reach out to the client for requirements clarification which may affect the project schedule. The fourth most common challenge is 'Incomplete Requirements' (33%). This is legitimate considering the fact that non-functional/quality requirements are usually given less importance during requirements gathering. Missing such requirements may cause project delays and sometimes to project failure. The fifth challenge of RE is 'Poor requirements traceability and interdependencies' (27%). This is due to the fact that collecting and maintaining traceability information is expensive. Traceability information usually involves recording the dependencies between requirements and the sources of the requirements, dependencies between requirements themselves and between requirements the system implementation/test cases. Hence, managing such activities is a bit difficult and tricky.

Challenges such as 'Poor requirements risk management,' 'Poor modeling of functional requirements,' 'Difficulties

[1] Available at https://docs.google.com/forms/d/e/1FAIpQLScI031iPhjLB-fGBv6cFQHe77Tr1bm6VjBX15_Tm-BrltNkkw/viewform .

Table 3 Ranking of the challenges identified as part of the mapping study

No.	Challenge	Freq (n=70)	Percentage (%)	Rank
1	Requirements change and evolution	32	46	1
2	Lack of clear understanding of system requirements by customer	27	39	2
3	Lack of sufficient domain knowledge and expertise by software engineers	25	36	3
4	Poor communication link	25	36	3
5	Incomplete requirements	23	33	4
6	Poor requirements traceability and interdependencies	19	27	5
7	Long feedback cycles to verify the requirements	18	26	6
8	Estimate uncertainties	17	24	7
9	Poor identification of stakeholders	16	23	8
10	Tight project schedule (shorter development times)	16	23	8
11	Conflict detection and resolution	15	21	9
12	Abstaining from allocating resources to RE	14	20	10
13	Failure to prioritize requirements	14	20	10
14	Requirements ambiguities and inconsistencies	13	19	11
15	Lack of ensuring stakeholders' satisfaction of the requirements	13	19	11
16	Cultural differences	11	16	12
17	Poor compliance with standard RE processes	11	16	12
18	Reuse of existing design in the wrong context and environment	7	10	13
19	Poorly defined specifications	6	9	14
20	Requirements analysis challenge	5	7	15
21	Change in technology	3	4	16
22	Difficulty in selecting suitable metrics	3	4	16
23	Organizational instability	3	4	16
24	Poor requirements risk management .	2	3	17
25	Poor modeling of functional requirements	2	3	17
26	Difficulties in formalizing requirements from natural language	2	3	17
27	Difficulty in implementing and improving RE within the organization	2	3	17

in formalizing requirements from natural language,' and 'Difficulty in implementing and improving RE within the organization,' are the least cited challenges with only 3% of the reviewed articles.

5.2 Classification of RE Challenges Based on RE Activities

A RE process is generally composed of the following four activities: feasibility study, requirements elicitation and analysis, requirements specifications, and requirements validation [3]. Although different software development life cycles (such as Waterfall, Agile, RUP, XP, etc.) have different RE processes, generally, they all share the same set RE activities. In this research, we rather focus on the activity not the RE process. The targeted challenges are general and can be applicable to any type of development methodology.

In order to categorize the challenges according to the RE activities, two co-authors of this paper carefully assessed each challenge and categorize it under one of the RE activities. This improves the authenticity of the categorization and helps in eliminating personal bias.

As shown in Tables 4, 5, 6 and 7, two (2) challenges are related to feasibility study activity, fifteen (15) challenges fall under the requirements elicitation and analysis activity, three (3) challenges are associated with requirements specification (documentation) activity, and three (3) challenges are linked to requirements validation. Moreover, as shown in Table 8, some of the challenges such as 'Poor compliance with standard RE processes' and 'Abstaining from Allocating Resources to RE' directly or indirectly affect all of RE activities, four (4) of such challenges are categorized under challenges that are related to all RE activities.

The following subsections present the detailed categorization of the identified challenges according to the different RE activities.

5.2.1 Challenges Faced During the Feasibility Study

The feasibility study, also known as the preparation phase, is the first step in any RE process. It aims to evaluate whether or not the proposed system is worthwhile. Conducting a feasibility study requires domain knowledge about the system to be developed, the stakeholders' intentions and goals, the project economics, and the competition. Table 4 presents the challenges related to this RE phase.

5.2.2 Challenges Faced During Requirements Elicitation and Analysis

Requirement elicitation and analysis is the process of interacting with stakeholders to discover and gather domain requirements, raw functional and non-functional requirements, and constraints of the system to be developed.

It is critical for a successful requirements elicitation that all the target system stakeholders are involved in the process from an early stage. Poor identification of stakeholders would hinder this activity and the whole project. Requirements elicitation has three main steps. The first step is related to the project concept clarification. The second step is about requirements gathering (using techniques such as brainstorming, interviews, focus groups, ethnography, etc.). In the last step, all raw requirements (that have been agreed upon by all stakeholders) are prepared for analysis. Requirements analysis aims to investigate of the elicited raw requirements to find different types of anomalies such as errors, inconsistencies, etc. Table 5 lists the challenges related to this RE phase.

5.2.3 Challenges Faced During Requirements Specification

Raw requirements are generally unorganized, lack many details, and are not written in a standard way. Hence, the formalization of raw requirements into a formal representation (e.g., using UML modeling technique) will help document all agreed upon requirements in a measurable, testable, and traceable way. The output of this phase is a requirements specification document (SRS) in the case of Waterfall methodology or a set of user stories in the case of agile, representing the requirements baseline. Table 6 lists the challenges related to this RE phase.

5.2.4 Challenges Faced During Requirements Validation

This RE activity deals with the validation and verification of the system requirements specifications. Requirements V&V ensures that the set of requirements (described in the SRS) is correct, complete, and consistent. Furthermore, it ensures that a real-world solution can be built and tested to prove that it satisfies the requirements. Requirements V&V can be achieved using inspection, prototyping, expert reviews, test cases generation, modeling, simulation, etc. Table 7 lists the challenges encountered during this RE phase.

It is worth noting that some challenges are encountered during more than one RE activity. Table 8 summarizes them.

6 Analysis of the Data Collected from IT Practitioners (RQ2)

To address research question RQ2, we have analyzed the responses collected from our questionnaire. Table 9 outlines the RE challenges faced by the 23 practitioners who participated in our study. The 23 participants work for fifteen different IT companies within four countries, namely the UK, Russia, Nigeria, and Saudi Arabia. The table shows three sub-segments:

1. The 'Positive' section that add-up the practitioners who either Strongly Agree (SA) or Agree (A) with the challenge.
2. The 'Negative' section that add-up the practitioners who either Strongly Disagree (SD) or Disagree (D) with the challenge.
3. The 'Neutral' section that add-up the practitioners who are Not Sure (NS) or did not encounter the challenge in their work.

Table 9 shows that all 31 reported challenges were concurred upon by at least 39% of the participants. Twenty six (26) out of these challenges were concurred upon by most of the participants (57%). The 'Change in requirements' and 'Requirements evolution' are the most frequent challenges in the 'Positive' section (87%). This is justifiable because the two high ranked challenges are indirectly related.

In the second position of the most common challenges, we find the 'Difficulty in identifying stakeholders in early stage of the project' and the 'Lack of sufficient domain knowledge and expertise by software engineers (83%).' Moreover, 'Requirement inconsistencies,' 'Incomplete requirements' and 'Long feedback cycles to verify the requirements' were reported as the third most significant challenges from practitioners' viewpoint. In the 'Negative' section, the percentages are lower than 30% for all of the challenges except for two, which are the 'Reuse of an existing design in the wrong context and environment' and 'Conflict detection' (35%). This indicates that approximately one-third of the 273 practitioners are not concerned about these two challenges. In the 'Neutral' section, the percentages are lower than 50% except for one i.e., 'Estimate uncertainties' (52%), which shows that the majority of the participants have some experience with all the 31 challenges except the 'Estimate uncertainties.' Even though,

Table 4 Challenges faced during the feasibility study

No.	Challenge	Percentage (%)	Rank
1	Lack of clear understanding of system requirements by customer	39	1
2	Lack of sufficient domain knowledge and expertise by software engineers	36	2

Table 5 Challenges faced during requirements elicitation and analysis

No.	Challenge	Percentage(%)	Rank
1	Poor communication link	36	1
2	Incomplete requirements	33	2
3	Poor requirements traceability and interdependencies	27	3
4	Estimate uncertainties	24	4
5	Poor identification of stakeholders	23	5
6	Tight project schedule (Shorter development times)	23	5
7	Conflict detection and resolution	21	6
8	Failure to prioritize Requirements	20	7
9	Requirements ambiguities and inconsistencies	19	8
10	Cultural differences	16	9
11	Requirements analysis challenge	7	10
12	Change in technology	4	11
13	Difficulty in selecting suitable metrics	4	11
14	Poor modeling of functional requirements	3	12
15	Poor requirements risk management	3	12

Table 6 Challenges faced during requirements specification

No.	Challenge	Percentage (%)	Rank
1	Reuse of an existing design in the wrong context and environment	10	1
2	Poorly defined specifications	9	2
3	Difficulties in formalizing requirements from natural language	3	3

Table 7 Challenges faced during requirements validation

No.	Challenge	Percentage (%)	Rank
1	Requirements change and evolution	46	1
2	Long feedback cycles to verify the requirements	26	2
3	Lack of ensuring stakeholders' satisfaction of the requirements	19	3

Table 8 Challenges faced during all RE activities

No.	Challenge	Percentage (%)	Rank
1	Abstaining from allocating Resources to RE	20	1
2	Poor compliance with standard RE processes	16	2
3	Organizational instability	4	3
4	Difficulty in implementing and improving RE within the organization	3	4

Table 9 Challenges identified via the questionnaire survey

RE challenges	Practitioners' perception (n = 23)							
	Positive			Negative			Neutral	
	Strongly Agree	Agree	%	Strongly Disagree	Disagree	%	Not sure	%
1. Change in requirements	8	12	87	0	0	0	3	13
2. Requirements evolution	5	15	87	0	0	0	3	13
3. Difficulty in identifying stakeholders in early stage of the project	7	12	83	0	1	4	3	13
4. Lack of sufficient domain knowledge and expertise by software engineers	5	14	83	3	1	17	0	0
5. Requirements inconsistencies	5	13	78	0	1	4	4	17
6. Incomplete requirements	9	9	78	0	3	13	2	9
7. Long feedback cycles to verify the requirements	5	13	78	0	0	0	5	22
8. Requirements ambiguities	5	12	74	0	0	0	6	26
9. Tight project schedule (Short software development period)	8	9	74	1	3	17	2	9
10. Not following standard RE activities	4	12	70	0	2	9	5	22
11. Difficulty in modeling functional requirements	3	13	70	1	4	22	2	9
12. Lack of clear understanding of system requirements by customer	10	5	65	0	5	22	3	13
13. Poor communication link between developers, customers, and analysts during requirements gathering	5	10	65	0	3	13	5	22
14. Poor risks management in requirements	2	13	65	0	3	13	5	22
15. Requirements prioritization	4	11	65	0		0	8	35
16. Change in technology	6	9	65	2	1	13	5	22
17. Difficulty in defining specifications	5	10	65	0	6	26	2	9
18. Analyzing requirements	6	9	65	3	3	26	2	9
19. Difficulty in getting stakeholders' acceptance	6	8	61	4	0	17	5	22
20. Difficulties in formalizing requirements from natural language	5	9	61	1	3	17	5	22
21. Difficulty in implementing and improving RE within the organization	4	10	61	2	2	17	5	22
22. Abstaining from allocating resources to RE	6	8	61	0	1	4	8	35
23. Tracking requirements dependencies	3	10	57	1	4	22	5	22
24. Reuse of an existing design in the wrong context and environment	1	12	57	1	7	35	2	9
25. Different stakeholders' backgrounds (experts from different professions, religion, cultural background, etc.)	2	11	57	1	5	26	4	17
26. Organizational instability	4	9	57	0	3	13	7	30
27. Conflict detection	2	9	48	1	7	35	4	17
28. Difficulty in selecting suitable metrics	1	10	48	2	3	22	7	30
29. Conflict resolution	1	9	43	0	3	13	10	43
30. Tracing requirements to other software artifacts	2	7	39	2	1	13	11	48
31. Estimate uncertainties	1	8	39	0	2	9	12	52

the practitioners were asked to include additional challenges if any; but, no one has added additional challenges, other than the ones collected from the mapping study.

6.1 Challenges Identified by Different Groups of Practitioners Based on Years of Experience (RQ2.1)

In our study, we divided the group of practitioners into two groups based on their years of experience. The first group is composed of software practitioners who have less than five years of experience, which represents 52% from the whole sample set, while the second group represents those who have five or more years of experience, which represents 48% of the whole sample set. Table 10 lists the identified challenges and analysis alongside each group. We computed the percentage of acceptance, which represents practitioners who agreed or strongly agreed with the challenge.

For the first group of practitioners, we notice that the majority had positive responses and agree with most of the challenges identified in the mapping study. The highest acceptance percentage was given to 'Change in requirements,' 'Lack of sufficient domain knowledge and expertise by software engineers,' 'Tight project schedule (short software development period),' and 'Incomplete requirements' which have the same agreement percentage (92%), followed by 'Difficulty in prioritizing requirements,' and 'Long feedback cycles to verify the requirements' which also have the same agreement percentage (83%). However, 'Conflict resolution,' 'Tracing requirements to other software artifacts,' 'Conflict detection,' 'Estimate uncertainties,' 'Difficulty in selecting suitable metrics,' and 'Abstaining from allocating resources to RE' challenges got low rates of acceptance by this group of practitioners. This observation may indicate that these challenges may not be among the serious issues faced by practitioners. The rest of the challenges received between 50% and 75% in terms of acceptance rate.

For the second group of practitioners, only two of the challenges received a high level of acceptance which are 'Requirements evolution,' and 'Difficulty in identifying stakeholders in the early stage of the project' which got an acceptance rate of 100%. The second-highest challenge in this group is 'Abstaining from allocating resources to RE' (91%), while 'Change in Requirements,' 'Poor communication link between stakeholders,' and 'Requirement inconsistencies' got the third high level of acceptance (82%). However, 'Tracing requirements to other software artifacts,' 'Organizational instability,' 'Estimate uncertainties,' 'Requirements prioritization,' 'Reuse of an existing design in the wrong context and environment,' and 'Tracking requirements dependencies,' received acceptance rates of 36%, 45%, 45%, 45%, 45%, and 45%, respectively. The rest of the challenges had between 55% and 73% acceptance rate among this group of practitioners, which are also considered as positive acceptance.

To compare the opinion of the two groups and identify the difference among them, we use the Fisher exact test which is a test of significance that can be used as an alternative to chi-square test in cases of small samples. Table 10 shows that for all challenges, there are no significant differences between the two groups of practitioners, since most of the p-value of the challenges are greater than the α value (i.e., 0.05). However, the test also shows that there is a significant difference in some cases such as 'Abstaining from allocating resources to RE,' and 'Not following standard RE activities' since their P-values are 0.042, and 0.045, respectively, which are less than 0.05.

6.2 Analysis of Challenges Based on Companies' Sizes (RQ2.2)

The size of an organization may impact the way an organization handles the RE process (as discussed in Sect. 3.1). To address research question RQ2.2, we divided the sample of 23 practitioners according to the company's size into three groups: small, medium and large. Companies which have less than 20 employees were considered small, whereas companies which have between 20 and 100 employees were considered as medium, and companies have more than 100 employees were considered as large. This classification is close to the one provided in [85]. Table 11 shows a statistical analysis of the results across the three groups. As shown in Table 11, the 23 practitioners were distributed as follows: 13 were from small companies, 4 from medium companies, and 6 from large companies. We note that all challenges were acknowledged (agreed upon) by 84% of practitioners from small companies, 88% of practitioners from medium companies, and 94% of practitioners from large companies.

To compare the opinion of the three groups, the Chi-square test was used to find out whether there is a significant difference in the challenges across different company sizes. Even though Table 11 shows that majority of the challenges have a p-value greater than 0.05, three challenges, namely 'Lack of sufficient domain knowledge and expertise by software engineers,' 'Change in technology,' and 'Difficulty in selecting suitable metrics' have p-values of 0.014, 0.011, and 0.045, respectively, which are less than 0.05. This means that there is significant differences across the three groups of practitioners with respect to these three specific challenges. Hence, a further investigation is required.

Table 10 Challenges based on years of experience

Challenges	Experience (< 5 *years*)						Experience ($>= 5$ *years*)						$\alpha = 0.05$
	SA	A	D	SD	NS	%	SA	A	D	SD	NS	%	
1. Change in requirements	4	7	0	0	1	92	4	5	0	0	2	82	0.961
2. Requirements evolution	1	8	0	0	3	75	4	7	0	0	0	100	0.309
3. Difficulty in identifying stakeholders in early stage of the project	2	6	0	1	3	67	5	6	0	0	0	100	0.272
4. Lack of clear understanding of system requirements by customer	4	4	2	0	2	67	6	1	3	0	1	64	0.715
5. Poor communication link between developers, customers, and analysts during requirements gathering	2	4	2	0	4	50	3	6	1	1	0	82	0.200
6. Requirements ambiguities	4	5	0	0	3	75	1	7	0	0	3	73	0.820
7. Requirements inconsistencies	2	7	1	0	2	75	3	6	0	0	2	82	1.000
8. Tracking requirements dependencies	3	6	0	0	3	75	1	4	4	0	2	45	0.246
9. Tracing requirements to other software artifacts	1	4	1	2	4	42	1	3	0	0	7	36	0.561
10. Lack of sufficient domain knowledge and expertise by software engineers	2	9	0	1	0	92	3	5	1	2	0	73	0.743
11. Conflict resolution	0	3	3	0	6	25	1	6	0	0	4	64	0.260
12. Conflict detection	0	5	3	1	3	42	2	4	4	0	1	55	0.520
13. Reuse of an existing design in the wrong context and environment	1	7	3	0	1	67	0	5	4	1	1	45	0.856
14. Tight project schedule (Short software development period)	4	7	0	0	1	92	4	2	3	1	1	55	0.103
15. Incomplete requirements	4	7	0	0	1	92	5	2	3	0	1	64	0.189
16. Poor risks management in requirements	0	9	0	0	3	75	2	4	3	0	2	55	0.118
17. Requirements prioritization	1	9	0	0	2	83	3	2	0	0	6	45	0.064
18. Not following standard RE activities	0	9	2	0	1	75	3	4	0	0	4	64	0.045
19. Change in technology	3	6	1	0	2	75	3	3	0	2	3	55	0.463
20. Different stakeholders' backgrounds (Experts from different professions, religion, cultural background, etc.)	1	5	2	1	3	50	1	6	3	0	1	64	0.848
21. Long feedback cycles to verify the requirements	1	9	0	0	2	83	4	4	0	0	3	73	0.393
22. Difficulty in getting stakeholders' acceptance	4	4	2	0	2	67	2	4	2	0	3	55	0.942
23. Difficulty in modeling functional requirements	2	7	2	0	1	75	1	6	2	1	1	64	1.000

Table 10 continued

Challenges	Experience (< 5 *years*)						Experience (>= 5 *years*)						$\alpha = 0.05$
	SA	A	D	SD	NS	%	SA	A	D	SD	NS	%	
24. Estimate uncertainties	0	4	2	0	6	33	1	4	0	0	6	45	0.800
25. Difficulty in defining specifications	2	6	4	0	0	67	3	4	2	0	2	64	0.645
26. Difficulties in formalizing requirements from natural language	3	3	2	1	3	50	2	6	1	0	2	73	0.720
27. Analyzing requirements	2	5	2	2	1	58	4	4	1	1	1	73	0.899
28. Difficulty in selecting suitable metrics	1	4	1	1	5	42	0	6	2	1	2	55	0.729
29. Difficulty in implementing and improving RE within the organization	2	5	1	1	3	58	2	5	1	1	2	64	1.000
30. Abstaining from allocating resources to RE	1	3	1	0	7	33	5	5	0	0	1	91	0.042
31. Organizational instability	2	6	0	0	4	67	2	3	3	0	3	45	0.470

SA strongly agree, *A* agree, *D* disagree, *SD* strongly disagree, *NS* not sure

7 Comparison of the Mapping Study and the Questionnaire Data (RQ3)

The RE challenges collected during the mapping study are analyzed against the challenges identified by the practitioners. We computed the recurrence of each challenge found in the literature. Similarly, the recurrence based on the 5-grade scale (strongly agree, agree, neutral, disagree, and strongly disagree) were computed for challenges collected via the questionnaire. Since the frequencies measured by means of the literature review were cumulative and the frequencies evaluated through the 5-grade scale were subjective, we have computed Spearman correlation coefficient [84] to scale these frequencies and distinguish similarities, contrasts, and relative reliance between the two sets of data collections. The Spearman correlation coefficient provides a direct reliance between two elements ranging from -1 to $+1$, with 1 being complete reliance, while negative values or zero indicate negative or absence of correlations, respectively.

The Spearman correlation coefficient is computed using the Spearman's rank-order relationship method to measure the significance of the resemblance in the challenges found from the literature and the questionnaire survey. The ranks are evaluated for all frequencies as shown in Table 12. The Spearman's relation coefficient value is ($r = 0.3061$) (Table 13), which suggest a weak positive relationship between the ranks of the two datasets. This weak positive relationship indicates that some of the challenges found in the literature are not perceived by participants to have a great impact in practice.

From Table 12, we can see that the practitioners' low ranked challenges such as 'Estimate uncertainties,' 'Tracing requirements to other software artifacts,' and 'Conflict resolution' which received low rank/percentage of acceptance from practitioner's perspectives(ranked 10–11, with 39–43% acceptance) are among the first 9 most frequent challenges that have high rank in the literature. Similarly, the challenge 'Lack of clear understanding of system requirements by customer' which is ranked as the 6th most common challenge from the practitioner's viewpoints, is ranked as the 2nd most frequent challenge in the literature. On another hand, challenges such as 'Difficulty in modeling functional requirements,' 'Poor risks management in requirements,' 'Change in technology,' 'Difficulties in formalizing requirements from natural language,' 'Difficulty in implementing and improving RE within the organization' which received a rank between 5 and 7 from the practitioner's point of view, received the lowest ranked in the literature (16–17) representing a big gap that contributed significantly to the weakness of the correlations between the two data.

8 Threats to Validity

Considerable care and attention has been made to ensure the rigor of this study. However, like any chosen research methodology, it is subject to threats to validity. Since conducting a systematic mapping study is a largely manual task, there is a risk that some relevant papers could have been missed. However, to mitigate this risk, we have followed

Table 11 Challenges based on the size of companies

Challenges	Small companies (n=13)					Medium companies (n=4)					Large companies (n=6)					χ^2 testα = 0.05
	SA	A	D	SD	NS	SA	A	D	SD	NS	SA	A	D	SD	NS	
1. Change in requirements	4	6	0	0	3	1	3	0	0	0	3	3	0	0	0	0.817
2. Requirements evolution	2	9	0	0	2	2	2	0	0	0	1	4	0	0	1	0.903
3. Difficulty in identifying stakeholders	3	7	1	0	2	1	2	0	0	1	3	3	0	0	0	0.886
4. Lack of clear understanding of system requirements by customer	5	4	3	0	1	1	1	1	0	0	4	0	0	0	2	0.476
5. Poor communication link	3	6	0	0	4	0	1	2	0	1	2	3	1	0	0	0.294
6. Ambiguity in requirements	4	7	0	0	2	0	2	0	0	2	1	3	0	0	2	0.858
7. Requirements inconsistencies	4	8	0	0	1	0	2	0	0	2	1	3	1	0	1	0.444
8. Tracking requirements dependencies	2	5	2	0	4	0	2	2	0	0	1	3	0	1	1	0.378
9. Tracing requirements to other software artifacts	1	4	1	1	6	0	2	0	1	1	1	2	0	0	3	0.852
10. Lack of sufficient domain knowledge and expertise by software engineers	2	10	1	0	0	0	1	0	3	0	3	3	0	0	0	0.014
11. Conflict resolution	0	4	2	0	7	0	2	0	0	2	1	3	1	0	1	0.659
12. Conflict detection	0	7	4	1	1	1	0	1	0	2	1	2	2	0	1	0.334
13. Reuse existing design in wrong context and environment	1	8	3	0	1	0	2	1	1	0	0	2	3	0	1	0.436
14. Tight project schedule	5	5	3	0	0	1	3	0	0	0	2	1	0	1	2	0.110
15. Incomplete requirements	5	5	2	0	1	2	2	0	0	0	2	2	1	0	1	0.969
16. Poor risks management in requirements	0	7	2	0	4	1	2	0	0	1	4	1	1	0	0	0.072
17. Requirements prioritization	1	8	0	0	4	1	1	0	0	2	2	2	0	0	2	0.825
18. Not following standard RE activities	3	8	1	0	1	1	2	1	0	0	0	2	0	0	4	0.164
19. Change in technology	3	7	0	0	3	1	0	1	2	0	3	1	0	0	2	0.011
20. Cultural differences	1	6	2	0	4	2	0	1	1	0	1	3	2	0	0	0.095
21. Long feedback cycles for verifying requirements	1	9	0	0	3	2	1	0	0	1	2	3	0	0	1	0.738
22. Difficulty in getting stakeholders' acceptance	4	4	2	0	3	1	2	1	0	0	1	2	1	0	2	0.957
23. Difficulty in modeling functional requirements	2	7	3	0	1	0	2	1	1	0	1	4	0	0	1	0.457
24. Estimates uncertainties	0	2	1	0	10	0	3	1	0	0	1	3	0	0	2	0.130
25. Difficulty in defining specifications	2	6	5	0	0	1	2	1	0	0	2	2	0	0	2	0.312
26. Difficulties in formalizing requirements from natural language	3	6	2	0	2	0	2	1	1	0	2	1	0	0	3	0.167
27. Analyzing requirements	4	4	2	1	2	1	1	0	2	0	1	4	1	0	0	0.314
28. Difficulty in selecting suitable metric	1	5	1	0	6	0	2	0	2	0	0	3	2	0	1	0.045

Table 11 continued

Challenges	Small companies (n=13)					Medium companies (n=4)					Large companies (n=6)					χ^2 testα = 0.05
	SA	A	D	SD	NS	SA	A	D	SD	NS	SA	A	D	SD	NS	
29. Difficulty in implementing and improving RE within the organization	2	5	1	0	5	1	1	0	2	0	1	4	1	0	0	0.051
30. Abstaining from allocating resources to RE	1	5	0	0	7	2	1	1	0	0	3	2	0	0	1	0.139
31. Organizational instability	3	6	1	0	3	0	2	0	0	2	2	1	2	0	1	0.591

SA strongly agree, *A* agree, *D* disagree, *SD* strongly disagree, *NS* not sure

closely the guidelines on conducting systematic mapping studies introduced by Petersen et al. [40]. Another related risk is that the selection process of papers included journal, conference/workshop papers only, while other types of publications, such as white papers, were excluded. White papers are not peer-reviewed. They are generally written by a company's in-house staff and may use facts to promote a certain product, service, or viewpoint. Hence, our paper selection is relatively valid and sound. Another threat related to the mapping study is about how the selected papers were mapped. To mitigate this threat, each paper is studied by two co-authors of this paper and any discrepancies about the extracted challenges are discussed and resolved.

Another possible threat is the small number of respondents (23 participants) who participated in the empirical study. More participants would have provided more confidence in our results and conclusions. In addition, only 15 companies were included in the study, which may represent a threat to the types of RE challenges they are facing. The last threat may be related to the location of the selected companies (UK, Russia, Saudi Arabia, and Nigeria), which may impact the types of the faced RE challenges. Extending our empirical study to covering more countries is part of our future work.

Furthermore, another possible threat related to the questionnaire is that the presented challenges might have been interpreted differently by the questionnaire respondents; hence affecting the study outcomes. However, none of the practitioners have reported that a challenge was not clear to him/her as the challenges were already defined and presented in a clear and concise way. Another risk might be the fact that our questionnaire presents a list of challenges and the respondents were asked to confirm or refute them using a 5-point Likert scale, and this may tend to preempt the responses as respondents may only focus on the challenges provided in the list. To mitigate this risk, practitioners were also given the chance to include additional challenges, if any. However, none was added.

Our mapping study is not context specific, i.e., specific development process, e.g., agile and waterfall, or specific product domain, e.g., automotive and business. Therefore, we did not identify the contexts of the studied papers, as such information may not be clearly stated, if present at all. This can be seen as another possible threat to validity. However, such classification is outside the scope of this paper.

Another possible concern is about how experience has been measured. To address RQ2.1, we used the number of years, the IT practitioner spent in the IT industry as an indicator of experience. However, this might not be an accurate measure of the quality of experience. In addition, another possible risk is with respect of our classification of corporation into small, medium, and large. In order to address RQ2.1, and given the absence of a common criteria for the 4 selected countries, we have considered small companies those with less than 20 employees, medium companies having between 20 and 100 employees, and large companies having more than 100 employees. The selected classification is close to the one provided in [85]. However, we expect that different definitions of number of employees ranges and different criteria may lead to different results.

9 Conclusions and Future Work

In this paper, we outlined the RE challenges discussed in the literature, using a systematic mapping study. A total of 27 RE challenges were extracted from a 70 papers that discuss RE challenges. These challenges were mapped to the different RE process activities. In addition, we have conduct an empirical study using a questionnaire to identify RE challenges faced by practitioners in the IT industry. The data are collected from 23 respondents who are working for fifteen different IT companies within four countries. Furthermore, we have investigated whether the types of faced challenges are related to the practitioner's experience and the company size. As expected, the top-ranked common challenges from both the mapping study and the questionnaire were (1) 'Change in Requirements,' (2) 'Requirements evolution,' (3) 'Lack of sufficient domain knowledge and expertise

Table 12 Comparison of the two datasets

RE Challenges	Agreed and strongly agreed challenge in the questionnaire survey (n=23)		Occurrence in literature (n= 70)		Average rank
	%	Rank	%	Rank	Av. Rank
1. Change in requirements	87	1	46	1	1
2. Requirements evolution	87	1	46	1	1
3. Difficulty in identifying stakeholders in early stage of the project	83	2	23	8	5
4. Lack of sufficient domain knowledge and expertise by software engineers	83	2	36	3	3
5. Requirements inconsistencies	78	3	19	11	7
6. Incomplete requirements	78	3	33	4	4
7. Long feedback cycles to verify the requirements	78	3	26	6	5
8. Requirements ambiguities	74	4	19	11	8
9. Tight project schedule (Short software development period)	74	4	23	8	6
10. Not following standard RE activities	70	5	16	12	9
11. Difficulty in modeling functional requirements	70	5	3	17	11
12. Lack of clear understanding of system requirements by customer	65	6	39	2	4
13. Poor communication link between developers, customers, and analysts during requirements gathering	65	6	36	3	5
14. Poor risks management in requirements	65	6	3	17	12
15. Requirements prioritization	65	6	20	10	8
16. Change in technology	65	6	4	16	11
17. Difficulty in defining specifications	65	6	9	14	10
18. Analyzing requirements	65	6	7	15	11
19. Difficulty in getting stakeholders' acceptance	61	7	19	11	9
20. Difficulties in formalizing requirements from natural language	61	7	3	17	12
21. Difficulty in implementing and improving RE within the organization	61	7	3	17	12
22. Abstaining from allocating resources to RE	61	7	20	10	9

Table 12 continued

RE Challenges	Agreed and strongly agreed challenge in the questionnaire survey (n=23)		Occurrence in literature (n=70)		Average rank
	%	Rank	%	Rank	Av. Rank
23. Tracking requirements dependencies	57	8	27	5	7
24. Reuse of an existing design in the wrong context and environment	57	8	10	13	11
25. Different stakeholders' backgrounds (Experts from different professions, religion, cultural background, etc.)	57	8	16	12	10
26. Organizational instability	57	8	4	16	12
27. Conflict detection	48	9	21	9	9
28. Difficulty in selecting suitable metrics	48	9	4	16	13
29. Conflict resolution	43	10	21	9	10
30. Tracing requirements to other software artifacts	39	11	27	5	8
31. Estimate uncertainties	39	11	24	7	9

Table 13 Spearman Correlation Matrix

Variables	Literature	Survey
Literature	**1**	0.3061
Survey	0.3061	**1**

by software engineers,' (4) 'Incomplete requirements,' and (5) 'Lack of clear understanding of system requirements by customer.' Our results show a weak positive relationship between the ranks obtained from the literature and the questionnaire-based empirical study. This weak positive relationship indicates that some of the challenges found in the literature are not considered as important challenges in practice. One reason may be due to the fact that organizations have successfully avoided some of these challenges.

As future work, we are planning to refine our study to include domain specific RE challenges and extend our empirical study to include more countries.

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