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Empirical Investigation of Critical Requirements Engineering Practices for Global Software Development

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ABSTRACT There is a need to identify requirements engineering (RE) practices that are important to global software development (GSD) project success. The objective of this paper is to report our recent empirical study results which aimed to identify the RE practices that are important to GSD projects. This study used an online survey questionnaire to elicit data from 56 RE experts of GSD projects. The survey included 66 RE practices identified by Sommerville *et al.* for non-GSD projects. The participants were asked to rank each RE practice on a four-point scale to determine the degree of importance of each practice in the context of GSD projects. This research identified a set of six key RE practices that mainly focuses on GSD project stakeholders, scope, standards and requirements traceability management. One common theme that is evident from the RE experts' feedback analysis is the standardization of requirements documents to reduce requirements inconsistencies and improve communication in diverse and distributed GSD project environments Our results show that not all 66 RE best practices are important for GSD projects. We believe that a good understanding of the identified RE practices is vital in developing and implementing the situation-specific RE processes for GSD projects.

INDEX TERMS Global software development (GSD), empirical study, requirements engineering (RE), software outsourcing.

I. INTRODUCTION

Global Software Development (GSD) offers several benefits to client companies outsourcing their development work to vendor companies. These benefits include cost savings, access to the global IT resource pool and round the clock development [1]. GSD is not an easy initiative and it poses several challenges due to global barriers of culture, time and distance. These challenges are mainly related to project communication and coordination in GSD [2]–[6].

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Although a variety of software development tasks are outsourced, previous work suggests that most of the factors contributing to the failure of outsourcing are related to requirements [7], [8]. This is not surprising given that the requirements engineering (RE) process significantly impacts the effectiveness of all software development processes [9] including GSD [10]. A previous UK study of non-outsourced projects found that out of 268 documented development problems, requirements problems accounted for 48% of them [11]. In another study of GSD projects, RE problems in multi-site software development organisations were identified [12]. Requirements in many projects

(GSD or not) are often constantly evolving and new requirements emerging [13]. Traditional on-site software development (in non-GSD projects) have always benefited from continuous collaboration between clients and developers [14]. This continuous collaboration leads to effective relationships which becomes the main enabler for projects to overcome the challenges of the ever changing requirements. Distributed development settings particularly hinder RE efforts as knowledge-acquisition and knowledge-sharing become far more challenging [15]. Moreover, distributed development settings hinder RE efforts due to lack of support for iterative processes that allow for requirements understanding to evolve with agility, leading to more frequent gaps of misunderstanding between client and vendor [16], [17].

It is evident that the problems in the requirements phase have a very detrimental impact on the success of software development projects [9], [11], [18] and an even greater impact on the success of the GSD projects [12], [19]. Eliciting and communicating requirements is identified as a major challenge in GSD in [20], [21]. It is acknowledged [22], [23] that globalization poses challenges to RE community and they need to devise new or extended existing techniques for tailoring and improving the situation-specific RE processes (requirements elicitation, analysis, negotiation, management etc.) for globally distributed GSD projects.

In order to tailor and improve a situation-specific RE process Sommerville and Sawyer [24] have suggested 66 RE practices. All of these RE practices were originated in the context of non-GSD projects and it is important to understand whether these RE practices are relevant and can be used in GSD projects. This demands empirical studies of RE practices in the context of GSD. Despite the importance of RE in GSD projects, no empirical study has been conducted to investigate the feasibility of these RE practices in GSD projects from practitioners' perspectives.

We propose that these 66 RE practices can be adapted to and tailored for GSD projects. We shared our initial study results on this topic in [25]. In order to further extend our initial study, this paper reports the results of an empirical study which aimed to identify RE practices that are considered critical (from practitioners' perspectives) for GSD projects. We address the following Research Questions (RQ) in this paper:

RQ1: Which RE practices are critical for GSD projects?

RQ2: Do the identified critical RE practices for GSD vary across the different expertise levels?

RQ3: Do the identified critical RE practices vary across experts from different company types?

RQ4: Are these critical RE practices related to the size of the GSD companies?

We have used the word ''critical'' in order to distinguish between practices which are (not) important to be considered by GSD companies. We considered an RE practice as a critical RE practice if it is reported as a highly important practice by at least 50% of the RE experts. This criterion has been used by other researchers as well [26]–[28].

In earlier research [25], we have addressed only RQ1 using data from 39 GSD RE experts. Recently, we collected responses from a larger number of GSD RE experts (i.e. 56). In addition to RQ1, we have also addressed RQ2-RQ4 in this paper.

The remainder of this paper is organized as follows. Section 2 presents the study background. Section 3 describes research methodology. Section 4 presents study results and analysis. Section 5 discusses the research findings. Finally, Section 6 concludes with study limitations and future work endeavours.

II. BACKGROUND AND RELATED WORK

Research shows that the percentage of software projects completed on-time and within budget improved from 34% in 2003 to 39% in 2012. Despite this improvement, 43% of the projects examined in the 2012 CHAOS report were 'challenged' (i.e., late, over budget or only partially successful) [29]. One of the main reasons for project failure is the complexity and significant changes made to the software development processes [30]–[32]. This complexity is further increased when software are developed in a distributed environment by global organizations [30], [33]–[35].

RE is the first activity of software development which plays a significant role in any project. Research shows that due to globalization, RE community needs to improve different RE processes in order to cope with diverse roles, collaboration needs, better decision making, cultural understanding, changing domain knowledge and organizational structures [34], [36]–[40]. In order to improve RE processes in GSD, we are interested to identify different practices, which can be used in different RE processes.

A. RE PRACTICES DESIGNED BY SOMMERVILLE AND SAWYER

Sommerville and Sawyer [24] suggested a generic requirements framework that includes 66 RE practices, which can be used to tailor and improve a situation-specific RE process for non-outsourced projects. These 66 RE practices are classified as basic, intermediate and advanced. There are 36 basic practices concerned with the fundamental activities required to gain control of the RE process; 21 intermediate practices mostly concerned with the use of methodical approaches and tools; and 9 advanced practices concerned with methods such as formal specification typically used for critical systems development. These 66 RE practices are grouped into 8 major categories:

1. Requirements documentation
2. Requirements elicitation.
3. Requirements analysis and negotiation.
4. Describing requirements.
5. System modelling.
6. Requirements validation.
7. Requirements management.

8. Requirements for critical systems (Note that we do not assess this category because none of the organizations involved in this study deal with critical systems.)

Thus far, no research work has considered using these 66 practices in GSD. Few studies have reported the use of these practices for non-outsourced projects such as [41] and [9]. It is important to study and identify RE practices that are important for GSD projects because earlier studies suggest that half of the companies that have tried GSD have failed to realize the anticipated outcomes, and the root cause of such failures is often related to RE problems [6], [7].

B. DEGREE OF IMPORTANCE (DOI)s

We assert that ''degree of importance'' (high to zero) of a particular RE practice can be used as a judgement criterion for determining the degree of importance of a particular RE practice for a GSD project from experts' perspectives. The degree of importance of RE practices can help researchers and practitioners to better understand the applicability of various RE practices within the context of GSD projects.

C. RELATED WORK

A number of empirical studies have been reported on RE practices since 2000. Nikula *et al.* [42], in an interview based study of 12 small to medium companies in Finland, identified that management is generally not aware that many RE issues can be solved by using existing standard RE practices available in the literature. They used top ten RE practices from the REAIMS (Requirements Engineering Adaptation and IMprovement for Safety and dependability) model by Sommerville and Sawyer [24] to assess the RE process maturity of the 12 surveyed companies. Majority of the surveyed companies were found to be lacking with respect to these top ten practices.

Neil and Laplante [43], through a survey study based on responses from 194 software professionals, identified that scenarios/use-cases and focus groups are the most frequently used requirements elicitation practices, while informal and semiformal approaches are preferred for modelling the requirements. They also observed that inspection walkthroughs and checklists are more frequently used requirements validation practices. This study reported specific techniques that support the generic practices proposed by Sommerville and Sawyer [24].

Gorschek *et al.* [44] presented a model of good practices to assess the maturity of requirements engineering process of a software company. Similar to Sommerville and Sawyer [24], the model groups the good practices in three areas: elicitation, analysis and negotiation, and management, and further organizes these practices in five maturity levels. They applied the model on cases from four different software companies to assess RE process maturity. Case companies were found to be not using the RE practices and actions of higher maturity levels. They found requirements management area to be the most lacking one in all four cases, and concluded that this area needs most improvements in the case companies. This study, as opposed to specific RE techniques (as discussed in Neil and Laplante [43]), discussed the clustering of RE practices into maturity levels.

In a field study on RE practice comprising 28 customer-projects in 16 different Australian software companies, Sadraei *et al.* [45] identified that RE effort is more evenly distributed across different activities of the RE process when the project has an internal customer. However, projects having external customers consume more effort and resources for the requirements analysis and management activities as compared to the requirements elicitation and validation. This study explored the effort and resource aspects of RE as opposed to the discovery of any new RE practices.

Talbot and Conner [46] conducted a survey of 30 small to medium companies in New Zealand to identify RE state of the practice. They identified that only 17% of the companies are using all ten RE guidelines to some extent proposed by Sommerville and Sawyer [24]. Furthermore, 65.4% companies were found to have an RE process with either clear phases with informal specifications, or formal process with semi-formal notation.

The analysis of related work indicates the relevance of RE framework proposed by Sommerville and Sawyer [24] and warrants the comprehensive study of RE practices in the modern context. Further, existing studies seem to focus on few practices and company size context (e.g., small to medium). Building on this valuable existing work, in this paper, we focus on the comprehensive analysis of 66 RE practices [24] in the modern context of GSD from a number of perspectives such as practitioners' experience (e.g., junior, intermediate and senior), company size (small, medium and large) and type (national and multinational).

III. RESEARCH METHODOLOGY

This section describes the data collection and analysis process.

A. DATA COLLECTION

Given the nature of this research, we decided to set up an online survey to collect data from RE practitioners of GSD organizations about their experiences in applying different RE practices in GSD projects. The survey research method is recommended when self-reported data from a large number of participants is to be elicited [47]. The survey research provides various techniques for data collection, such as interviews, questionnaires, or a conjuncture of them [48]. We used the questionnaire method since our goal was to gather data about the applicability of generic or non-GSD RE practices in GSD projects from a large and dispersed population. The questionnaire was developed based on the generic 66 RE practices designed by Sommerville and Sawyer [24]. The questionnaire contains mostly closed-ended questions that were used to elicit specific data from experts. The questionnaire also contains few open-ended questions to elicit any additional RE practices that are not part of the 66 RE practices of [24]. The questionnaire is available from authors.

TABLE 1. Summary of LinkedIn outsourcing/GSD related groups.

Group	Members
Global Outsourcing and Offshoring (IT)…	4070
Global Software Development Collaboration	1409
Global Software Engineering	493
ICT Outsourcing Professionals	833
IT/Software Development Outsourcing and Offshoring	11247
Offshoring and Outsourcing Forum	5412
Outsourcing and Offshoring	24401
Outsourcing 2 India	5831
Outsourcing in the Central and Eastern Europe	655
Outsourcing to Ukraine	1232
Outsourcing@UK	3939

Initially, a pilot study was conducted with five RE experts to validate the questionnaire. The questionnaire was finalized based on the pilot study feedback. The finalized questionnaire was divided into three sections: Section 1 elicits the expert's basic details; Section 2 elicits demographics data; and Section 3 elicits experts perspectives about the 66 RE practices. In addition, the first page of the survey provided the basic information about the research project. In order to assure the participants about the confidentiality of their data, a statement regarding researchers' ethical responsibility was also included at the beginning of the questionnaire. This statement was used to assure the participants that their data will only be accessible to the research team. It was made clear that the research team will not share the data with anyone in a manner that could disclose any participant or organization identity.

As stated earlier, our target population was large and dispersed across the globe. We decided to use unconventional means to get the responses from RE experts involved in GSD. We used two basic means for requesting the RE experts to participate in our survey. Firstly, we sent emails to 19 GSD RE experts using our personal contacts and 11 agreed to participate. Secondly, we joined GSD related groups on LinkedIn. Table 1 presents the details of the groups. We identified 178 RE experts relevant to our research by viewing through their available profiles at the LinkedIn groups and retrieved their available email addresses. Amongst the 178 experts, identified through LinkedIn groups, 52 experts participated in the survey. Each completed response was checked and out of 63 ($11 + 52$) complete responses, we left out 7 responses as the expertise shared by these 7 participants were not relevant to GSD and/or RE context. 56 completed and final responses were considered valid and included in this study, hence, the final response rate is summed up to 28%.

Each RE expert was asked to choose and rank 66 RE practices against four types of assessments that have been adapted from earlier studies [9], [24], [49]. These assessments were:

- High Importance (H): A practice has a documented standard and is always followed as part of the organisation's GSD process, i.e. it is mandatory.
- Medium Importance (M): This means that the practice is widely followed in the organisation's GSD process but it is not mandatory.
- Low Importance (L): Some GSD projects may have introduced the practice and consider the practice to be least beneficial.
- Zero Importance (Z): The practice is never or rarely applied to any GSD projects.

This assessment list is used to determine the ''degree of importance'' (high to zero) of each RE practice, i.e. the degree of importance placed on a RE practice by experts based on their experience from previous GSD projects.

We used responses from 56 GSD RE experts for data analysis. Experts were RE practitioners with GSD/outsourcing experience levels ranging from 1 year (minimum) to 17 years (maximum) with an average experience level of 6 years. 71% of the participants were from multinational companies. Most of the participants' companies develop business applications and data processing applications. Out of 56 experts, 27 work in large companies (staff size greater than 200) and 19 work in medium size companies (staff size between 20 and 200).

B. DATA ANALYSIS

In order to analyse the importance of each identified RE practice, the degree of importance (high, medium, low, zero) in each response was counted. By comparing the occurrences of one RE practice's importance against the occurrences of other RE practices' importance, the relative importance of each RE

TABLE 2. Highly important RE practices.

ID	Practice	Frequency n=56	RE Category
RD1	Define a standard document structure	24	Documentation
RD3	Include summary of the requirements	26	
RE3	Identify and consult system stakeholders	36	Elicitation
RA1	Define system boundaries	29	Analysis & Negotiation
RA5	Prioritise requirements	30	
DR1	Define standard templates for describing requirements	28	Description
DR3	Use diagrams appropriately	25	
SM3	Model the system architecture	18	Modelling
RV1	Check that the requirements document meets your standards	28	Validation
RM1	Uniquely identify each requirement	28	Management

practice was identified. In our earlier work [49], [50], we also used this approach to identify high and low valued RE practices and software process improvement de-motivators [51]. Most of the data analysis was performed using statistical analysis. We have applied linear by linear Chi-Square test on our ordinal data to identify significant differences between the responses from different expert groups. Linear-by-linear Chi-Square test is preferred over the Pearson test when testing the significant difference between ordinal variables [52].

IV. RESULTS AND ANALYSIS

A. RQ1-RE PRACTICES CRITICAL FOR GSD: OVERALL ANALYSIS

Fifty six (56) GSD RE experts participated in this survey and expressed their experiences about the 66 RE practices for GSD projects. We have divided these experts into three categories (senior, intermediate and junior) based on their experience. Details of these categories are provided in section 4.2. Thirty four percent of the experts (34%) were junior level practitioners. Forty one percent of the experts (41%) were intermediate level practitioners. Twenty five percent of the experts (25%) were senior level practitioners. This indicates a good spread and representation of a diverse population of GSD experts. The responses of the 56 GSD RE experts are presented in Appendix A. Table 2 lists the highly important RE practices for GSD.

Interestingly, RE3 (*identify and consult system stakeholders*) is the highly important practice reported in our study (i.e., 64%). This RE practices is difficult to execute in GSD projects because of stakeholders' temporal, geographical and socio-cultural distance. In GSD, system stakeholders are often not directly accessible to the development team. There is a need to carefully plan to facilitate the interaction between system stakeholders and development team. Different techniques and their combinatorial use, such as video conferencing, occasional visits of key project members across sites etc., can be adopted to facilitate this interaction.

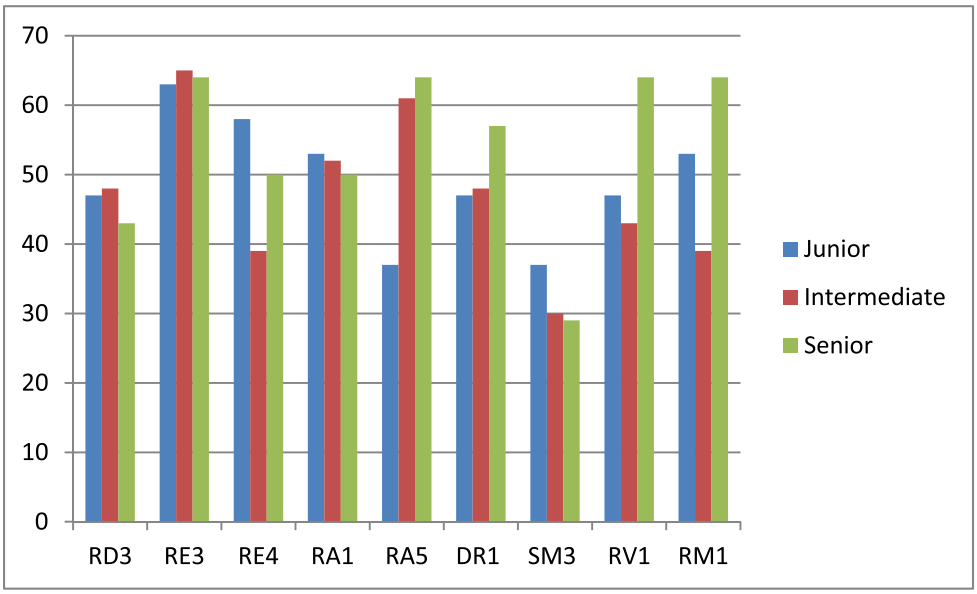
In the "Analysis and Negotiation" category, RA5 (*Prioritise requirements*) is perceived to be the second highly important RE practice. Requirements prioritization becomes critical in iterative and incremental development where one has to identify critical requirements and decides what features to be included in each increment and iteration in order to maximize the stakeholder satisfaction and return on investment.

In our study, 52% of the participants reported RA1 (*define system boundaries)* as a highly important RE practice for GSD projects. A GSD team will often insist on defining the system boundary of a new system in order to better understand the problems and scope of the system. This system boundary reflects the mutual understanding of developers and the sponsoring organisation and also provides engineers with a starting point to estimate project effort.

One pattern that is evident here is that RE experts give high importance to standardization of requirements documents. The use of templates and standardized requirements documents helps reduce inconsistencies and improves the overall quality of requirements documents in GSD projects. One of the major challenges in GSD is knowledge management [53]–[56]. This issue is compounded when client and vendor companies have different cultures, different notations, local templates and nomenclature. Standardization may help remedy these problems.

B. RQ2-RE PRACTICES FOR GSD IN THE OPINION OF JUNIOR, INTERMEDIATE AND SENIOR LEVEL EXPERTS

Experts who participated in the survey have varying levels of experience of working in GSD projects. They provided their feedback based on their work history and the environment they have worked in their careers. It is important to note that the experts' feedback may or may not reflect the opinions of their previous or current employer. We divided these experts into three categories based on their experience. The first category is about junior level experts who have experience of less than five years in GSD projects. Second category is



Category	Practice	Category	Practice
Documentation	RD3 Include a summary of the requirements	Description	DR1 Define standard templates for describing requirements
Elicitation	RE3 Identify and consult system stakeholders RE4 Record requirements sources	Modelling	SM3 Model the system architecture
		Validation	RV1 Check that the requirements document meets your standards
Analysis	RA1 Define system boundaries RA5 Prioritise requirements	Management	RM1 Uniquely identify each requirement

FIGURE 1. Summary of RE practices for GSD based on practitioners' experience.

about intermediate level experts who have experience of less than 10 years but more than 5 years of experience in GSD projects. Finally, experts with 10 years or above experience are categorized as senior level experts. There is no such specific categorization of GSD experts that is available in literature. Therefore, based on our discussions with GSD experts, we categorized experts based on their experience. Other researchers may devise and use other criteria in order to classify experts into different categories.

The summary of the highly important RE practices is provided in Figure 1. Appendix B provides the detailed analysis. All experts rated RE 3 (*Identify and consult system stakeholders*) and RA1 (*define system boundaries*) as the highly important RE practices (>=50%) for GSD projects. Further analysis of the results show that junior and senior level experts considered RE4 (*record requirements sources*) and RM1 (*uniquely identify each requirement*) as the highly important RE practices for GSD projects. Intermediate and senior level experts rated RA5 (*prioritise requirements*) as the highly important (>=60%) RE practice for GSD projects.

We applied Chi-Square linear by linear association test on highly important practices (see Table 3a). It can be observed from Table 3 that the "P" value for all the RE practices is greater than 0.05. For instance, P value for RD3 practice is 0.813, which indicates that all three groups of practitioners (Junior, Intermediate and Senior) have a common consensus on the importance of RD3 practice for GSD projects. This means that approx. 47% Junior, 47% Intermediate and 42 % Senior practitioners cited RD 3 as one of the highly important practices. There is no significant difference across highly important RE practices as identified by all three groups of practitioners for GSD projects. This means that all three RE expert groups have a common agreement upon the importance of these RE practices for GSD projects.

C. RQ3-RE PRACTICES FOR GSD BY RE PRACTITIONERS OF MULTINATIONAL AND NATIONAL COMPANIES

Companies are involved in GSD projects in different organizational settings. There are multinational companies who have offices in different countries. Some offices are in vendor locations such as India and Pakistan, while others are in client locations like USA or Europe. There are national companies in vendor destinations like India and Pakistan. These national companies receive outsourced projects directly from clients in USA or Europe. In our survey 40 of the 56 practitioners work in multinational companies and 13 in national companies. Three practitioners responded with a "don't know" option to this question for eliciting company

TABLE 3. (a) Statistical analysis of RE practices for GSD based on practitioners' experience. (b) Summary of RE practices for GSD based on company type.

(a)

RE Category	Practice	Total Frequency n=56	Practitioners Experience: Junior n=19	Intermediate n=23	Senior n=14	Chi-square Test (Linear-by-Linear Association) α = .05 df = 1 X^2	P
Documentation	RD3 Include summary of the requirements	26	9	11	6	.056	.813
Elicitation	RE3 Identify and consult system stakeholders	36	12	15	9	.163	.686
	RE4 Record requirements sources	27	11	9	7	.042	.838
Analysis & Negotiation	RA1 Define system boundaries	29	10	12	7	.020	.886
	RA 5Prioritise requirements	30	7	14	9	2.655	.103
Description	DR1 Define standard templates for describing requirements	28	9	11	8	.272	.602
Modeling	SM3 Model the system architecture	18	7	7	4	.268	.604
Validation	RV1 Check that the requirements document meets your standards	28	9	10	9	.745	.385
Management	RM1 Uniquely identify each requirement	28	10	9	9	.272	.602

(b)

Category	Practice	Category	Practice
Documentation	RD1 Define a standard document structure	Description	DR1 Define standard templates for describing requirements
	RD6 Make document layout readable	Modelling	SM3 Model the system architecture
Elicitation	RE3 Identify and consult system stakeholders	Validation	RV1 Check that the requirements document meets your standards
	RE4 Record requirements sources		
Analysis	RA1 Define system boundaries	Management	RM1 Uniquely identify each requirement
	RA5 Prioritise requirements		

type. Practitioners provided their feedback based on their work history and environment they have worked in their careers. It is important to note that the experts' feedback may or may not be impacted by the type of their current employer company. In order to further understand the importance of RE practices for GSD projects, we further analysed the feedback based on the current company type of the respondents.

Detailed responses of the RE experts from multinational companies and national companies are shown in Appendix C. The summary of the highly important RE practices for GSD projects is provided in Figure 2. RE 3 (*identify and consult system stakeholders*), RV1 (*check that the requirements document meets your standards*) and RM1 (*uniquely identify each requirement*) are the most commonly cited highly important practice (>=50%) by the participants of multinational and national companies. Our results show that more than half of the multinational companies' participants consider RE4 (*record requirements sources*), RA1 (*define system boundaries*), RA5 (*prioritise requirements*) and DR1 (*define standard templates for describing requirements*) as highly important RE practices for GSD projects. Figure 2 shows that 54% of the national companies' participants consider RD6 (*make document layout readable*) as a highly important practice.

Table 4 presents the results of the linear by linear Chi-Square test on practices listed in Figure 2. It can be observed from Table 4 that the "P" value for all the RE practices is greater than 0.05. For instance, P value for RD1 practice is 0.879, which indicates that practitioners from

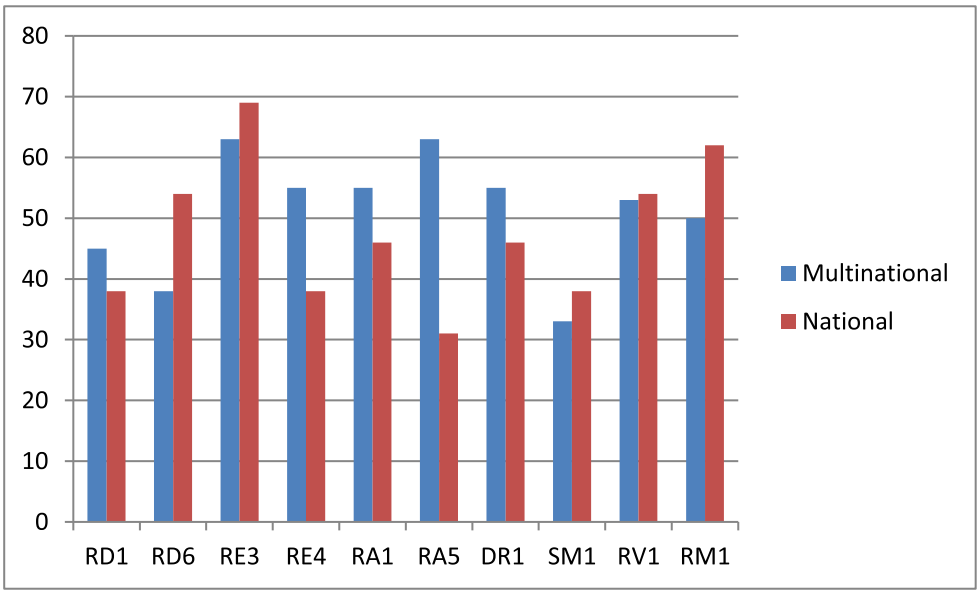


FIGURE 2. Summary of RE practices for GSD based on company type.

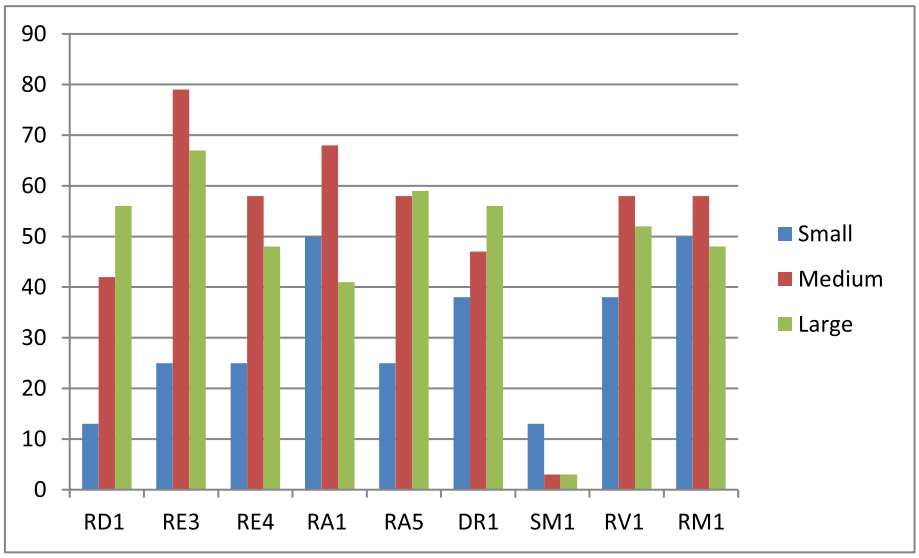
TABLE 4. Statistical analysis of RE practices for GSD based on company type.

RE Category	Practice	Total Frequency n=56	Practitioners Experience: National n=13	Practitioners Experience: Multi national n=40	Practitioners Experience: Not Known n=3	Chi-square Test (Linear-by-Linear Association) α = .05 df = 1: X^2	Chi-square Test (Linear-by-Linear Association) α = .05 df = 1: P
Documentation	RD1 Define a standard document structure	24	5	18	1	.023	.879
	RD6 Make document layout readable	22	7	15	1	1.023	.312
Elicitation	RE3 Identify and consult system stakeholders	36	9	24	2	.166	.684
	RE4 Record requirements sources	27	5	22	0	.009	.925
Analysis & Negotiation	RA1 Define system boundaries	29	6	22	1	.009	.925
	RA 5Prioritise requirements	30	4	25	1	1.543	.214
Description	DR1 Define standard templates for describing requirements	28	6	22	0	.276	.599
Modeling	SM3 Model the system architecture	18	5	13	0	1.010	.315
Validation	RV1 Check that the requirements document meets your standards	28	7	21	0	1.106	.293
Management	RM1 Uniquely identify each requirement	28	8	20	0	2.487	.115

all three types of companies have a common consensus on the importance of RD1 practice for GSD projects. This means that approx. 38% National, 45% Multinational and 33 % Not Known types of companies' experts cited RD1 as one of the highly important practices. There is no significant difference between the feedback obtained from multinational and national participants.

D. RQ4-RE PRACTICES FOR GSD IN THE OPINION OF GSD EXPERTS OF DIFFERENT COMPANY SIZE

The GSD experts, who participated in this study, come from companies of varying sizes. Some come from very small companies consisting of few employees while others come from very large companies consisting of dozens of employees. We used organization size definitions given by Australian Bureau of Statistics [57] to categorise the companies based on their size. This approach has already been used in a similar study in [28]. We divided companies into three categories: small (less than 20 employees), medium (20 to 199 employees) and large (200 + employees). Responses from RE experts from these three companies sizes are given in Appendix D. Out of 56 participants, 8 experts are from small companies, 19 from medium-sized companies, 27 from large companies and 2 experts were not sure



Category	Practice	Category	Practice
Documentation	RD1 Define a standard document structure	Description	DR1 Define standard templates for describing requirements
		Modelling	SM3 Model the system architecture
Elicitation	RE3 Identify and consult system stakeholders RE4 Record requirements sources	Validation	RV1 Check that the requirements document meets your standards
Analysis	RA1 Define system boundaries RA5 Prioritise requirements	Management	RM1 Uniquely identify each requirement

FIGURE 3. Summary of RE practices for GSD based on company size.

about their company size. Practitioners provided their feedback based on their work history and environment they have worked in their careers. It is important to note that the experts' feedback may or may not be impacted by the size of their current employer company. In order to further understand the importance of RE practices for GSD projects, we further analysed the feedback based on the current company size of the respondents.

Figure 3 shows that no practice has been identified as commonly cited (>=50%) among small, medium and large sized companies participants. RA1 (*define system boundaries*) and RM1 (*uniquely identify each requirement*) are the highly important RE practices (>=50%) for GSD projects from the perspectives of participants that come from small and medium sized companies. RE 3 (*identify and consult system stakeholders*), RA5 (*prioritise requirements*) and RV1 (*check that the requirements document meets your standards*) are the highly important RE practices (>=50%) for GSD projects from the perspectives of participants that come from medium and large size companies. Further, the analysis results are also shown based on the individual company sizes: participants from medium sized companies consider RE4 (*record requirements sources*) as a highly important RE practice for GSD projects; participants from large sized companies consider RD1 (*define a standard document structure*) and DR1 (*define standard templates for describing requirements*) as highly important RE practices for GSD projects.

Table 5 shows the results of the linear by linear Chi-Square test, which was applied to RE practices. The results show that all the RE experts from all company sizes have no significant differences in experiences with respect to RE practices listed in Figure 3. It can be observed from Table 5 that the ''P'' value for all the RE practices is greater than 0.05. For instance, P value for RD1 practice is 0.152, which indicates that practitioners from all types of companies have a common consensus on the importance of RD1 practice. This means that approx. 42% Medium and 55 % Large types of companies' experts cited RD1 as one of the highly important practices for GSD projects.

V. SUMMARY OF FINDINGS

In this study, 56 RE experts provided their experience-based feedback about the applicability or importance of traditional 66 RE practices of Sommerville and Sawyer for GSD projects. GSD organizations and practitioners can use the identified highly important RE practices

TABLE 5. Statistical analysis of RE practices for GSD based on company type.

RE Category	Practice	Total Frequency n=56	Company Size				Chi-square Test (Linear-by-Linear Association) α = .05 df = 1	
			Small n=8	Medium n=19	Large n=27	Not Known n=2	X^2	P
Documentation	RD1 Define a standard document structure	24	1	8	15	0	2.051	.152
Elicitation	RE3 Identify and consult system stakeholders	36	2	15	17	1	.861	.354
	RE4 Record requirements sources	26	2	11	13	1	.428	.513
Analysis & Negotiation	RA1 Define system boundaries	29	4	13	11	1	.993	.319
	RA5Prioritise requirements	30	2	11	16	1	1.592	.207
Description	DR1 Define standard templates for describing requirements	28	3	9	15	1	.732	.392
Modeling	SM3 Model the system architecture	18	1	7	10	0	.347	.556
Validation	RV1 Check that the requirements document meets your standards	28	3	11	14	0	.029	.864
Management	RM1 Uniquely identify each requirement	28	4	11	13	0	.732	.392

TABLE 6. Summary of RE practices for RQ1.

Category	Practice	High value responses out of N= 56	
		Freq	%
Elicitation	RE3 Identify and consult system stakeholders	36	64
Analysis and Negotiation	RA5 Prioritise requirements	30	54
Analysis and Negotiation	RA1 Define system boundaries	29	52
Description	DR1 Define standard templates for describing requirements	28	50
Validation	RV1 Check that the requirements document meets your standards	28	50
Management	RM1 Uniquely identify each requirement	28	50

(from practitioners' perspectives) for tailoring and improving the situation-specific RE processes for their GSD projects. We considered an RE practice as a critical RE practice if it is reported as a highly important practice by at least 50% of the RE experts. This criterion has been used by other researchers as well [26]–[28]. We suggest that GSD companies should consider using, if not already using, these critical RE practices in their RE practice toolbox for GSD projects. This section discusses the research findings and links it back to the original four research questions (RQ1-RQ4).

A. RQ1: WHICH RE PRACTICES ARE CRITICAL FOR GSD PROJECTS?

In order to address RQ1, we identified the six critical RE practices for GSD projects by using the above mentioned criterion (of at least 50% of the RE experts). These critical RE practises are shown in Table 6. Three RE practices (RE3, RA5 and RA1) relate to technical execution of the requirements engineering phase. These three practices have been previously discussed in Section 4.1. Meanwhile, the other three practices (DR1, RV1 and RM1) are closely related together in the realm of facilitating the requirements engineering phase. To further clarify, it is common to find companies using standard templates for describing requirements as templates tend to prompt authors to provide complete information that would have otherwise been overlooked (DR1). One of the most important fields required in standard template is identification numbers for the various components and artefacts (RM1). Together DR1 and RM1 are important criteria in checking that "*the requirements documents meet*

TABLE 7. Summary of RE practices for RQ1.

Category	Practice	Talbot and Connor (2011)	Nikula et. al (2000)	Neill and Laplante (2003)	Sadraei et. al (2007	Gorschek et. al (2003)
Elicitation	RE3 Identify and consult system stakeholders	No	No	Yes	Yes	Yes
Analysis and Negotiation	RA5 Prioritise requirements	No	No	No	Yes	Yes
Analysis and Negotiation	RA1 Define system boundaries	No	No	No	No	Yes
Description	DR1 Define standard templates for describing requirements	Yes	Yes	Yes	Yes	Yes
Validation	RV1 Check that the requirements document meets your standards	Yes	Yes	Yes	No	No
Management	RM1 Uniquely identify each requirement	Yes	Yes	No	No	Yes

TABLE 8. Summary of findings for RQ2.

Expert Level	RE Practice critical for GSD
Junior (n=19)	Following practices are identified as critical • **RE3-Identify and consult system stakeholders (63%)** • RE4-Record requirements sources (58%) • **RA1-Define system boundaries (53%)** • RM1-Uniquely identify each requirement (53%)
Intermediate (n=23)	Following practices are identified as critical • **RE3-Identify and consult system stakeholders (65%)** • **RA1-Define system boundaries (52%)** • RA4-Prioritise requirements (61%)
Senior (n=14)	Following practices are identified as critical • RD1-Define a standard document structure (57%) • **RE3-Identify and consult system stakeholders (64%)** • **RA1-Define system boundaries (50%)** • RA4-Prioritise requirements (64%) • DR1-Define standard templates for describing requirements (57%) • RV1-Check that the requirements document meets your standards (64%) • RM1-Uniquely identify each requirement (64%)

your standard" (RV1). The fact that the latter three practices (DR1, RV1 and RM1) have all been scored equally denotes their close association.

The six identified critical RE practices for GSD were compared with previous studies on RE practices as shown in Table 7. DR1 is used and recommended by all of the five previous studies as shown in Table 7. These results show that the definition and use of templates for describing requirements have been found useful in variety of contexts. RE3, RV1 and RM1 have been used in three previous studies,

TABLE 9. Summary of findings for RQ3.

Company type of expert	RE Practice critical for GSD
Multinational (n=40)	Following practices are identified critical • RD3-Include a summary of the requirements (50%) • RE3-Identify and consult system stakeholders (63%) • RE4-Record requirements sources (55%) • RA1-Define system boundaries (55%) • RA4-Prioritise requirements (63%) • DR1-Define standard templates for describing requirements (55%) • RV1-Check that the requirements document meets your standards (53%) • RM1-Uniquely identify each requirement (50%)
National (n=13)	Following practices are identified as critical • RD6-Make document layout readable (54%) • RE3-Identify and consult system stakeholders (69%) • RE5-Define the system's operating environment (54%) • RV1-Check that the requirements document meets your standards (54%) • RM1-Uniquely identify each requirement (62%)

TABLE 10. Summary of findings for RQ4.

Company Size	RE Practice critical for GSD
Small (n=8)	Following practices are identified as critical • RD6-Make document layout readable (50%) • RE5-Define the system's operating environment (50%) • RE12-Define operational processes (50%) • RA1-Define system boundaries (50%) • RM1-Uniquely identify each requirement (50%)
Medium (n=19)	Following practices are identified as critical • RE3-Identify and consult system stakeholders (79%) • RE4-Record requirements sources (58%) • RA1-Define system boundaries (68%) • RA5-Prioritise requirements (58%) • RV1-Check that the requirements document meets your standards (58%) • RM1-Uniquely identify each requirement (58%)
Large (n=27)	Following practices are identified as critical • RD1-Define a standard document structure (56%) • RD3-Include a summary of the requirements (63%) • RE3-Identify and consult system stakeholders (67%) • RE5-Define the system's operating environment (52%) • RA1-Define system boundaries (50%) • RA5-Prioritise requirements (59%) • DR1-Define standard templates for describing requirements (56%) • RV1-Check that the requirements document meets your standards (52%)

while RA5 has been recommended in two previous studies. RA1, i.e. "Define system boundaries", has only been recommended in one study. The results in Table 7 suggest that three practices (RE3, RA5 and RA1) have not been used and recommended very frequently in previous studies. However, these three practices are identified as the top three practices in our study (see Table 6). Software practitioners, working in GSD projects, find these practices critical in their context.

B. RQ2: DO THE IDENTIFIED CRITICAL RE PRACTICES FOR GSD VARY ACROSS THE DIFFERENT EXPERTISE LEVELS?

Table 8 summarizes our findings for RQ2. Table 8 outlines critical RE practices based on the criterion described above. Senior level RE experts ranked seven practices as critical. Whereas junior and intermediate level experts recommended four and three RE practices, respectively, as critical for GSD projects. Two practices RE3 and RA1 are commonly

TABLE 11. Overall results of the empirical study.

ID	Requirements Documents Practice	Type of Assessment (n=56)			
		H	M	L	Z
RD 1	Define a standard document structure	24	22	9	1
RD 2	Explain how to use the document	16	22	16	2
RD 3	Include a summary of the requirements	26	23	5	2
RD 4	Make a business case for the system	19	25	9	3
RD 5	Define specialized terms	18	22	14	2
RD 6	Make document layout readable	23	25	6	2
RD 7	Help readers find information	13	29	10	4
RD 8	Make the document easy to change	13	35	4	4
	Requirements analysis and negotiation practices				
RA 1	Define system boundaries	29	18	7	2
RA 2	Use checklists for requirements analysis	18	19	15	4
RA 3	Provide software to support negotiations	10	17	23	6
RA 4	Plan for conflicts and conflict resolution	17	19	16	4
RA 5	Prioritise requirements	30	23	2	1
RA 6	Classify requirements using a multi-dimensional approach	14	17	21	4
RA 7	Use interaction matrices to find conflicts and overlaps	7	14	25	10
RA 8	Assess requirements risks	18	19	14	5
	System Modelling Practices				
SM 1	Develop complementary system models	11	22	17	6
SM 2	Model the system's environment	12	19	20	5
SM 3	Model the system architecture	18	25	8	5
SM 4	Use structured methods for system modelling	15	21	13	7
SM 5	Use a data dictionary	15	18	17	6
SM 6	Document the links between stakeholder requirements and system models	13	18	19	6
	Requirements Management Practices				
RM 1	Uniquely identify each requirement	28	17	8	3
RM 2	Define policies for requirements management	17	19	16	4
RM 3	Define traceability policies	17	18	14	7
RM 4	Maintain a traceability manual	15	14	19	8
RM 5	Use a database to manage requirements	16	17	12	11
RM 6	Define change management policies	17	21	10	8

ID	Requirements Elicitation Practices	Type of Assessment (n=56)			
		H	M	L	Z
RE1	Assess System Feasibility	21	27	6	2
RE2	Be sensitive to organisational and political consideration	19	21	14	2
RE3	Identify and consult system stakeholders	36	16	3	1
RE4	Record requirements sources	27	22	6	1
RE5	Define the system's operating environment	26	22	6	2
RE6	Use business concerns to drive requirements elicitation	20	25	7	4
RE7	Look for domain constraints	23	19	11	3
RE8	Record requirements rationale	15	18	18	5
RE9	Collect requirements from multiple viewpoints	16	25	11	4
RE10	Prototype poorly understood requirements	11	24	16	5
RE11	Use scenarios to elicit requirements	16	26	9	5
RE12	Define operational processes	20	23	10	3
RE13	Reuse requirements	11	29	11	5
	Describing Requirements Practices				
DR1	Define standard templates for describing requirements	28	17	8	3
DR2	Use languages simply and concisely	21	28	5	2
DR3	Use diagrams appropriately	25	18	7	6
DR4	Supplement natural language with other description of requirement	19	26	9	2
DR5	Specify requirements quantitatively	12	23	18	3
	Requirements validation Practices				
RV1	Check that the requirements document meets your standards	28	16	7	5
RV2	Organise formal requirements inspections	15	18	17	6
RV3	Use multi-disciplinary teams to review requirements	16	16	17	7
RV4	Define validation checklists	17	17	15	7
RV5	Use prototyping to animate requirements	9	20	18	9
RV6	Write a draft user manual	20	17	13	6
RV7	Propose requirements test cases	20	21	10	5
RV8	Paraphrase system models	5	19	24	8
	Requirements Engineering for Critical Systems Practices				
CS1	Create safety requirement checklists	15	18	9	14
CS2	Involve external reviewers in the validation process	9	20	12	15
CS3	Identify and analyse hazards	16	15	14	11

TABLE 11. *(Continued.)* **Overall results of the empirical study.**

RM 7	Identify global system requirements	18	16	12	10		CS4	Derive safety requirements from hazard analysis	14	16	13	13
RM 8	Identify volatile requirements	11	17	18	10		CS5	Cross-check operational and functional requirements against safety requirement	16	11	16	13
RM 9	Record rejected requirements	10	11	23	12		CS6	Specify systems using a formal specification	12	20	13	11
							CS7	Collect incident experience	12	17	14	13
							CS8	Learn from incident experience	18	17	10	11
							CS9	Establish an organizational safety culture.	10	23	12	11

H=High, M=Medium, L=Low, Z=Zero

RD= Requirements document practices, RE = Requirements elicitation practices, RA= Requirements analysis and negotiation practices, DR= Describing requirements practices, SM= System modelling practices, RV= Requirements validation practices, RM= Requirements management practices, CS= RE for critical systems practices

perceived as critical by all three expert groups whereas RA4 is common between intermediate and seniors. There are practices that are uniquely rated as critical by only one expert group. These are RE4 by juniors, and DR1, RD1 and RV1 by seniors. It is clear from table 8 that differences in the experiences of these three types of experts are due to the senior level experts. These differences are due to the three RE practices (DR1, RD1 and RV1) rated as critical only by seniors. All these three practices are RE practices related to standardization. It can be argued that seniors, through their experience, have realized the importance of RE practices related to standardization in GSD projects. Standardization helps in dealing with knowledge management related problems in GSD.

C. RQ3: DO THE IDENTIFIED CRITICAL RE PRACTICES VARY ACROSS EXPERTS FROM DIFFERENT COMPANY TYPES?

Table 9 outlines the summary of our findings for RQ3. RE experts working in multinational companies rated 8 practices as critical for GSD projects while experts from national companies rated 5 practices as critical. Three practices (RE3, RV1 and RM1) are common between both types of companies. It can be inferred that there are more differences and fewer similarities between RE experts from multinational and national companies. It can be inferred that the type of a company does have an impact on what is considered as critical RE practice in GSD projects. National companies, usually smaller in size, receive downstream work of software development life cycle from client companies. They are not engaged extensively in RE phase. On the other hand multinational companies are more involved in whole life cycle and are more involved in the RE phase. Considering this fundamental difference in the nature of GSD work, the differences between experts from multinational and national companies are understandable. We recommend that GSD companies and experts should plan to implement and improve practices listed in table 9.

D. RQ4: ARE THESE CRITICAL RE PRACTICES RELATED TO THE SIZE OF THE GSD COMPANIES?

Table 10 presents the summary of findings for RQ4. RE experts from small, medium and large companies recommended 5, 6 and 8 practices as critical, respectively. Overall, there are more differences and fewer similarities across the three groups. One practice (RA1) is a commonly cited RE practice by experts from all three company sizes. RM1 is commonly cited as a critical RE practice by both small and medium company experts. RE5 is commonly cited as a critical RE practice by both small and large company experts. Between the medium and large company experts, three practices (RE3, RA5 and RV1) are commonly cited as high value practices. We recommend that the practices recommended as critical by experts of small, medium and large companies should be considered for adoption by GSD managers in their companies.

VI. LIMITATIONS

This study used the questionnaire based method for data collection from 56 RE experts. One limitation of using a questionnaire is that it usually consists of closed-ended questions whereby participants choose one option from given multiple options. This close-ended question-answer style tends to influence the output of the questionnaire. We dealt with this problem by including open-ended questions whereby we asked RE experts to list down any other RE practices, not already included in the questionnaire, which they consider important in GSD projects. Further, this paper does not map the different contexts such as outsourcing models and project domains to different RE practices. The only context given is that of company size. The RE study reported in this paper provides a generic set of RE practice that can be tailored to a

TABLE 12. RE practices for GSD based on practitioners' experience.

		Junior (N=19)				Intermediate(N=23)				Senior(N=14)			
ID	Practice	H	M	L	Z	H	M	L	Z	H	M	L	Z
RD1	Define a standard document structure	7	7	4	1	9	11	3	0	8	4	2	0
RD2	Explain how to use the document	6	6	5	2	6	11	6	0	4	5	5	0
RD3	Include a summary of the requirements	9	7	2	1	11	10	2	0	6	6	1	1
RD4	Make a business case for the system	7	6	3	3	7	12	4	0	5	7	2	0
RD5	Define specialized terms	6	8	3	2	8	9	6	0	4	5	5	0
RD6	Make document layout readable	8	8	1	2	10	9	4	0	5	8	1	0
RD7	Help readers find information	4	10	3	2	7	10	4	2	2	9	3	0
RD8	Make the document easy to change	6	10	0	3	4	16	3	0	3	9	1	1
RE1	Assess System Feasibility	6	10	2	1	8	12	3	0	7	5	1	1
RE2	Be sensitive to organisational and political consideration	5	7	5	2	8	9	6	0	6	5	3	0
RE3	Identify and consult system stakeholders	12	5	1	1	15	7	1	0	9	4	1	0
RE4	Record requirements sources	11	6	1	1	9	12	2	0	7	4	3	0
RE5	Define the system's operating environment	9	7	2	1	11	10	2	0	6	5	2	1
RE6	Use business concerns to drive requirements elicitation	7	9	0	3	8	11	4	0	5	5	3	1
RE7	Look for domain constraints	9	2	7	1	9	11	2	1	5	6	2	1
RE8	Record requirements rationale	6	4	6	3	6	9	8	0	3	5	4	2
RE9	Collect requirements from multiple viewpoints	7	6	4	2	5	13	5	0	4	6	2	2
RE10	Prototype poorly understood requirements	4	6	5	4	4	13	5	1	3	5	6	0
RE11	Use scenarios to elicit requirements	7	6	2	4	4	16	3	0	5	4	4	1
RE12	Define operational processes	7	7	4	1	6	14	2	1	7	2	4	1
RE13	Reuse requirements	5	9	3	2	3	11	8	1	3	9	0	2
RA1	Define system boundaries	10	5	3	1	12	9	2	0	7	4	2	1
RA2	Use checklists for requirements analysis	7	6	3	3	8	8	7	0	3	5	5	1
RA3	Provide software to support negotiations	6	3	9	1	3	8	11	1	1	6	3	4
RA4	Plan for conflicts and conflict resolution	7	6	5	1	7	6	10	0	3	7	1	3
RA5	Prioritise requirements	7	10	1	1	14	8	1	0	9	5	0	0
RA6	Classify requirements using a multi-dimensional approach	5	5	7	2	6	7	9	1	3	5	5	1
RA7	Use interaction matrices to find conflicts and overlaps	4	2	8	5	2	8	9	4	1	4	8	1
RA8	Assess requirements risks	7	4	4	4	7	8	8	0	4	7	2	1
DR1	Define standard templates for describing requirements	9	5	3	2	11	8	4	0	8	4	1	1
DR2	Use languages simply and concisely	7	9	2	1	7	13	3	0	7	6	0	1
DR3	Use diagrams appropriately	7	5	3	4	11	9	2	1	7	4	2	1
DR4	Supplement natural language with other description of reqs.	6	9	3	1	9	11	3	0	4	6	3	1
DR5	Specify requirements quantitatively	6	4	7	2	4	13	6	0	2	6	5	1
SM1	Develop complementary system models	5	7	4	3	3	11	8	1	3	4	5	2
SM2	Model the system's environment	5	5	6	3	4	11	8	0	3	3	6	2
SM3	Model the system architecture	7	8	2	2	7	12	3	1	4	5	3	2
SM4	Use structured methods for system modelling	5	6	4	4	7	10	5	1	3	5	4	2
SM5	Use a data dictionary	5	5	5	4	7	9	7	0	3	4	5	2
SM6	Document the links between stakeholder reqs and system models	6	6	3	4	5	8	9	1	2	4	7	1
RV1	Check that the requirements document meets your standards	9	6	2	2	10	8	4	1	9	2	1	2
RV2	Organise formal requirements inspections	5	6	5	3	5	8	9	1	5	4	3	2
RV3	Use multi-disciplinary teams to review requirements	6	5	3	5	6	7	10	0	4	4	4	2
RV4	Define validation checklists	7	3	6	3	5	10	6	2	5	4	3	2
RV5	Use prototyping to animate requirements	5	3	7	4	2	13	6	2	2	4	5	3
RV6	Write a draft user manual	6	4	6	3	9	8	5	1	5	5	2	2
RV7	Propose requirements test cases	7	5	6	1	9	9	3	2	4	7	1	2
RV8	Paraphrase system models	1	6	10	2	3	9	9	2	1	4	5	4
RM1	Uniquely identify each requirement	10	5	3	1	9	10	4	0	9	2	1	2
RM2	Define policies for requirements management	6	4	7	2	6	10	6	1	5	5	3	1
RM3	Define traceability policies	7	5	5	2	5	10	5	3	5	3	4	2
RM4	Maintain a traceability manual	6	5	5	3	5	7	8	3	4	2	6	2
RM5	Use a database to manage requirements	5	7	2	5	7	7	7	2	4	3	3	4
RM6	Define change management policies	6	5	4	4	6	10	4	3	5	6	2	1
RM7	Identify global system requirements	5	2	7	5	9	9	3	2	4	5	2	3
RM8	Identify volatile requirements	5	2	7	5	4	11	6	2	2	4	5	3
RM9	Record rejected requirements	4	2	8	5	4	7	8	4	2	2	7	3
CS1	Create safety requirement checklists	5	5	2	7	6	8	5	4	4	5	2	3
CS2	Involve external reviewers in the validation process	4	4	4	7	3	11	5	4	2	5	3	4
CS3	Identify and analyse hazards	7	4	4	4	7	7	5	4	2	4	5	3
CS4	Derive safety requirements from hazard analysis	4	5	3	7	6	9	4	4	2	4	6	2
CS5	Cross-check operational/functional reqs against safety reqs	6	3	3	7	6	6	7	4	3	3	6	2
CS6	Specify systems using a formal specification	6	4	4	5	5	10	6	2	1	6	3	4
CS7	Collect incident experience	6	2	6	5	4	11	4	4	2	4	4	4
CS8	Learn from incident experience	7	3	5	4	8	8	4	3	3	6	1	4
CS9	Establish an organizational safety culture.	4	6	5	4	5	11	4	3	1	6	3	4

H=High, M=Medium, L=Low, Z=Zero

TABLE 13. RE practices for GSD based on company size.

		Small(N=8)				Intermediate(N=19)				Large (N=27)			
ID	Practice	H	M	L	Z	H	M	L	Z	H	M	L	Z
RD1	Define a standard document structure	1	6	1	0	8	6	5	0	15	9	3	0
RD2	Explain how to use the document	1	6	1	0	4	4	10	1	11	11	5	0
RD3	Include a summary of the requirements	2	6	0	0	7	7	4	1	17	9	1	0
RD4	Make a business case for the system	0	4	3	1	5	10	3	1	13	11	3	0
RD5	Define specialized terms	1	4	3	0	3	8	7	1	13	10	4	0
RD6	Make document layout readable	4	4	0	0	6	9	3	1	12	12	3	0
RD7	Help readers find information	0	7	0	1	2	9	6	2	10	13	4	0
RD8	Make the document easy to change	2	6	0	0	2	12	3	2	9	16	1	1
RE1	Assess System Feasibility	2	5	1	0	7	7	4	1	11	15	1	0
RE2	Be sensitive to organisational and political consideration	2	3	2	1	3	7	9	0	14	10	3	0
RE3	Identify and consult system stakeholders	2	4	2	0	15	3	1	0	18	9	0	0
RE4	Record requirements sources	2	6	0	0	11	5	3	0	13	11	3	0
RE5	Define the system's operating environment	4	4	0	0	8	7	4	0	14	10	2	1
RE6	Use business concerns to drive requirements elicitation	0	7	0	1	8	5	5	1	11	13	2	1
RE7	Look for domain constraints	3	3	2	0	7	6	5	1	12	10	4	1
RE8	Record requirements rationale	0	5	2	1	7	5	5	2	8	7	11	1
RE9	Collect requirements from multiple viewpoints	1	3	3	1	4	10	4	1	11	12	3	1
RE10	Prototype poorly understood requirements	2	2	3	1	3	6	7	3	6	15	6	0
RE11	Use scenarios to elicit requirements	2	4	1	1	6	7	4	2	8	14	4	1
RE12	Define operational processes	4	3	1	0	5	8	4	2	11	11	5	0
RE13	Reuse requirements	0	6	2	0	3	11	2	3	8	11	7	1
RA1	Define system boundaries	4	2	2	0	13	4	2	0	11	12	3	1
RA2	Use checklists for requirements analysis	3	1	4	0	6	9	2	2	8	9	9	1
RA3	Provide software to support negotiations	1	3	4	0	2	5	10	2	6	9	9	3
RA4	Plan for conflicts and conflict resolution	3	2	3	0	3	9	6	1	10	8	7	2
RA5	Prioritise requirements	2	6	0	0	11	7	1	0	16	10	1	0
RA6	Classify requirements using a multi-dimensional approach	2	4	1	1	1	7	11	0	11	6	8	2
RA7	Use interaction matrices to find conflicts and overlaps	1	2	5	0	1	5	8	5	5	7	11	4
RA8	Assess requirements risks	3	2	2	1	5	6	6	2	10	10	6	1
DR1	Define standard templates for describing requirements	3	3	2	0	9	6	2	2	15	8	4	0
DR2	Use languages simply and concisely	2	6	0	0	4	13	2	0	14	9	3	1
DR3	Use diagrams appropriately	2	3	3	0	7	8	2	2	15	7	2	3
DR4	Supplement natural language with other description of reqs.	3	4	1	0	2	11	6	0	13	11	2	1
DR5	Specify requirements quantitatively	1	2	5	0	2	6	9	2	9	14	4	0
SM1	Develop complementary system models	1	2	3	2	3	9	4	3	7	11	9	0
SM2	Model the system's environment	0	2	5	1	4	7	5	3	8	10	9	0
SM3	Model the system architecture	1	4	3	0	7	7	2	3	10	13	3	1
SM4	Use structured methods for system modelling	0	3	3	2	5	8	3	3	10	9	7	1
SM5	Use a data dictionary	0	3	3	2	2	7	8	2	13	8	5	1
SM6	Document links between stakeholder reqs, and system models	0	4	4	0	4	5	6	4	9	9	8	1
RV1	Check that the requirements document meets your standards	3	3	2	0	11	4	2	2	14	8	3	2
RV2	Organise formal requirements inspections	2	2	2	2	4	7	6	2	9	9	8	1
RV3	Use multi-disciplinary teams to review requirements	2	2	2	2	1	8	8	2	13	6	6	2
RV4	Define validation checklists	3	1	3	1	2	7	8	2	12	9	3	3
RV5	Use prototyping to animate requirements	1	1	5	1	2	6	6	5	6	13	6	2
RV6	Write a draft user manual	2	1	4	1	4	7	5	3	14	8	4	1
RV7	Propose requirements test cases	1	4	3	0	3	9	4	3	16	7	3	1
RV8	Paraphrase system models	0	1	7	0	0	4	11	4	5	14	5	3
RM1	Uniquely identify each requirement	4	2	2	0	11	3	4	1	13	11	2	1
RM2	Define policies for requirements management	2	3	3	0	4	6	7	2	11	10	5	1
RM3	Define traceability policies	2	3	2	1	4	5	7	3	11	10	4	2
RM4	Maintain a traceability manual	2	3	2	1	4	2	10	3	9	9	6	3
RM5	Use a database to manage requirements	1	2	3	2	4	7	5	3	11	8	3	5
RM6	Define change management policies	1	2	2	3	5	6	6	2	11	12	2	2
RM7	Identify global system requirements	1	3	2	2	5	4	6	4	12	8	4	3

TABLE 13. ***(Continued.)*** **RE practices for GSD based on company size.**

RM8	Identify volatile requirements	0	2	4	2	3	4	9	3	8	11	4	4
RM9	Record rejected requirements	0	1	5	2	3	2	11	3	7	8	6	6
CS1	Create safety requirement checklists	0	4	1	3	5	5	3	6	10	9	4	4
CS2	Involve external reviewers in the validation process	0	3	2	3	1	6	6	6	8	11	3	5
CS3	Identify and analyse hazards	2	3	0	3	6	3	5	5	8	9	8	2
CS4	Derive safety requirements from hazard analysis	1	3	1	3	3	5	4	7	8	10	7	2
CS5	Cross-check operational/functional reqs against safety req.	2	1	2	3	5	2	5	7	8	9	8	2
CS6	Specify systems using a formal specification	2	3	1	2	5	5	4	5	5	12	7	3
CS7	Collect incident experience	1	3	2	2	3	4	4	8	8	10	7	2
CS8	Learn from incident experience	2	3	1	2	6	2	4	7	10	12	4	1
CS9	Establish an organizational safety culture.	1	3	2	2	3	5	5	6	6	15	4	2

H=High, M=Medium, L=Low, Z=Zero

specific context by GSD organisations for tailoring their own context-specific RE processes and models.

Internal validity provides confidence in the overall assessment of the results. The questionnaire was developed using 66 RE practices proposed by Sommerville and Sawyer [24] and in consultation with GSD experts. A pilot study was conducted to validate the questionnaire and its results provide an acceptable level of validity. Results of the pilot study were reported in [58].

External validity is concerned with the generalization of results to contexts and situations other than that in which original study was conducted [59]. The sample size of participants from the small companies was too small (i.e., 8 our of 56) which is one of the limitations of this study. External validity is addressed in our study as our results are based on experiences of 56 experts from 12 different countries including all major clients (e.g. USA, UK and Australia) and vendor (India and Pakistan) destinations. We cannot conclude that all GSD experts from these 12 countries would agree with 56 participants of this study. However we do believe that they provide a reasonable representative sample.

We also have one limitations.

VII. CONCLUSION AND FUTURE WORK

We identified through this empirical study RE practices which are perceived to be critical for GSD projects by RE experts. We recommend that in order to address Requirements-related challenges in GSD, managers of GSD projects should pay close attention to these identified critical RE practices for GSD projects.

Our objective is to provide GSD managers with a body of knowledge that can help them to tailor and implement situation-specific RE practices and processes for GSD projects according to their specific business context (e.g. outsourcing model, project domain, project size, project team size, agile and non-agile Waterfall development) and goals. The RE practices, reported in this paper, may be further used to develop RE process maturity models (similar to CMMI staged or continuous model). GSD managers may focus more on frequently cited RE practices in Table 2 and Appendix A (RQ1). GSD managers, who are interested to know the perspectives of junior, intermediate and senior level experts, may look at the frequently cited RE practices in Table 3 and Appendix B (RQ2). GSD manager, who are interested to know the perspectives of experts that come from national and multinational companies, may look at the frequently cited RE practices in Table 4 and Appendix D (RQ3). GSD managers, who are interested to know the perspectives of the experts that come from different organisation sizes (small, medium and large), may look at the frequently cited RE practices in Table 5 and Appendix C (RQ4). This paper analyses, organizes and reports the experts perspectives' on critical RE practices for GSD from multi-dimensions. The results of this study have not only implications for GSD managers. The findings of this study can also be used by planning and initiating further research streams in GSD RE. From the findings of this study, we have identified the following goals that we plan to pursue in future research:

- Observation of the RE practices that work for organization engaged in GSD. This observation may help to identify any new RE practices or challenges.
- Development of a RE framework for GSD (GlobReq) to improve RE in GSD projects. The basis of the GlobReq framework will be on well-known Sommerville and Sawyer's framework of requirements practices [24]; empirical study with GSD organisations; and our questionnaire based survey. Empirical data from GSD organisations and practitioners will be used to construct and validate the GlobReq framework. The following initial criteria will be used for the development of the GlobReq framework. This approach has successfully been used in previous empirical research with software development organisations [49], [60].
  - User satisfaction: Stakeholders (e.g. requirements engineers, systems analysts, outsourcing project staff) should be able to use GlobReq to achieve specified goals according to their needs and expectations without confusion or ambiguity.
  - Ease of use: The structure and contents of GlobReq should be simple, flexible and easy to follow [61].
  - Better requirements: GlobReq should aid the development of high quality requirements (e.g. less ambiguous, more comprehensive, consistent and feasible).

TABLE 14. RE practices for GSD based on company type.

		Multinational(N=40)				National(N=14)			
ID	Practice	H	M	L	Z	H	M	L	Z
RD1	Define a standard document structure	18	15	6	1	5	5	2	0
RD2	Explain how to use the document	13	14	11	2	5	6	2	0
RD3	Include a summary of the requirements	20	16	2	2	3	7	3	0
RD4	Make a business case for the system	16	16	5	3	6	5	2	0
RD5	Define specialized terms	13	17	8	2	3	7	3	0
RD6	Make document layout readable	15	21	2	2	7	4	2	0
RD7	Help readers find information	11	18	8	3	1	10	2	0
RD8	Make the document easy to change	10	25	1	4	3	8	2	0
RE1	Assess System Feasibility	16	20	2	2	5	5	3	0
RE2	Be sensitive to organisational and political consideration	14	15	10	1	4	5	3	1
RE3	Identify and consult system stakeholders	25	12	2	1	9	3	1	0
RE4	Record requirements sources	22	15	2	1	5	5	3	0
RE5	Define the system's operating environment	18	17	4	1	7	3	2	1
RE6	Use business concerns to drive requirements elicitation	15	18	3	4	4	6	3	0
RE7	Look for domain constraints	17	11	10	2	6	5	1	1
RE8	Record requirements rationale	14	8	14	4	1	8	3	1
RE9	Collect requirements from multiple viewpoints	13	16	8	3	3	7	2	1
RE10	Prototype poorly understood requirements	9	17	10	4	2	6	5	0
RE11	Use scenarios to elicit requirements	12	20	4	4	4	4	4	1
RE12	Define operational processes	17	15	7	1	3	7	2	1
RE13	Reuse requirements	9	21	7	3	2	7	3	1
RA1	Define system boundaries	22	11	5	2	6	6	1	0
RA2	Use checklists for requirements analysis	13	12	12	3	4	6	2	1
RA3	Provide software to support negotiations	9	12	15	4	1	4	6	2
RA4	Plan for conflicts and conflict resolution	14	14	10	2	3	4	4	2
RA5	Prioritise requirements	25	13	1	1	4	8	1	0
RA6	Classify requirements using a multi-dimensional approach	12	11	14	3	2	4	7	0
RA7	Use interaction matrices to find conflicts and overlaps	6	9	18	7	1	4	7	1
RA8	Assess requirements risks	15	14	7	4	3	4	5	1
DR1	Define standard templates for describing requirements	22	12	4	2	6	4	2	1
DR2	Use languages simply and concisely	17	18	3	2	4	8	1	0
DR3	Use diagrams appropriately	20	10	5	5	5	6	2	0
DR4	Supplement natural language with other description of req.	15	17	6	2	4	7	2	0
DR5	Specify requirements quantitatively	11	13	14	2	1	8	3	1
SM1	Develop complementary system models	8	14	13	5	3	6	3	1
SM2	Model the system's environment	9	13	14	4	3	4	5	1
SM3	Model the system architecture	13	20	4	3	5	4	2	2
SM4	Use structured methods for system modelling	11	14	9	6	4	5	3	1
SM5	Use a data dictionary	13	10	12	5	2	6	4	1
SM6	Document links between stakeholder reqs and system models	11	11	14	4	2	6	4	1
RV1	Check that the requirements document meets your standards	21	11	5	3	7	3	2	1
RV2	Organise formal requirements inspections	11	12	13	4	4	5	2	2
RV3	Use multi-disciplinary teams to review requirements	12	12	10	6	4	3	5	1
RV4	Define validation checklists	13	10	12	5	4	5	3	1
RV5	Use prototyping to animate requirements	7	13	13	7	2	5	5	1
RV6	Write a draft user manual	17	10	9	4	3	5	4	1
RV7	Propose requirements test cases	17	15	6	2	3	5	3	2
RV8	Paraphrase system models	5	15	16	4	0	3	8	2
RM1	Uniquely identify each requirement	20	14	4	2	8	2	2	1
RM2	Define policies for requirements management	14	12	11	3	3	6	4	0
RM3	Define traceability policies	13	14	10	3	4	3	4	2
RM4	Maintain a traceability manual	12	10	13	5	3	3	6	1
RM5	Use a database to manage requirements	15	9	8	8	1	6	4	2
RM6	Define change management policies	15	12	7	6	2	8	2	1
RM7	Identify global system requirements	16	9	9	6	2	6	2	3
RM8	Identify volatile requirements	8	14	12	6	3	2	5	3
RM9	Record rejected requirements	7	9	16	8	3	1	6	3
CS1	Create safety requirement checklists	13	12	7	8	2	5	1	5
CS2	Involve external reviewers in the validation process	8	15	9	8	1	4	2	6
CS3	Identify and analyse hazards	14	9	12	5	2	5	1	5
CS4	Derive safety requirements from hazard analysis	11	10	11	8	1	6	2	4
CS5	Cross-check operational/ functional reqs against safety req.	13	9	10	8	2	2	5	4
CS6	Specify systems using a formal specification	10	16	9	5	2	3	2	6
CS7	Collect incident experience	12	11	10	7	0	5	3	5
CS8	Learn from incident experience	16	11	6	7	2	5	2	4
CS9	Establish an organizational safety culture.	10	16	9	5	0	6	3	4

High, M=Medium, L=Low, Z=Zero

- Validation of GlobReq: GlobReq will be handed over to an expert panel comprising of GSD experts from organizations who did not participate in data collection process. Criteria described above (i.e. User Satisfaction, Ease of use and Better requirements) will be used as the basis of the evaluation. These experts will be selected on the basis of their practical and/or academic experience with GSD projects. Expert feedback will be used to update and improve the GlobReq framework before it is finalized for use in the software industry.

We believe that a good understanding of the identified RE practices is vital in developing and implementing the situation-specific RE processes for GSD projects. A sub-set of the highlighted RE practices can be selected and tailored to create a context-specific agile or non-agile (e.g. Waterfall) RE process by using a metamodel based method engineering approach [62]. The research presented in this paper is a starting point and we encourage further empirical studies in this important area of RE and GSD research.

APPENDIX A

See Table 11.

APPENDIX B

See Table 12.

APPENDIX C

See Table 13.

APPENDIX D

See Table 14.

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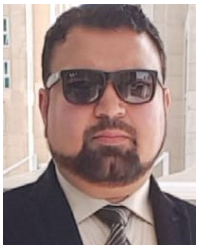

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