Empirical Investigation of Critical Requirements Engineering Practices for Global Software Development

HABIB ULLAH KHAN1, (Member, IEEE), MAHMOOD NIAZI2,3, MOHAMED EL-ATTAR4, NAVEED IKRAM5, SIFFAT ULLAH KHAN6,7, AND ASIF QUMER GILL8

1Department of Accounting and Information Systems, College of Business and Economics, Qatar University, Doha, Qatar
2Department of Information and Computer Science, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia
3Interdisciplinary Research Center for Intelligent Secure Systems, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia
4Department of Software Engineering, Alfaisal University, Riyadh 11533, Saudi Arabia
5Faculty of Computing, Riphah International University, Islamabad 46000, Pakistan
6Department of Software Engineering, University of Malakand, Chakdara 18800, Pakistan
7Department of Computer Science & IT, University of Malakand, Chakdara 18800, Pakistan
8School of Computer Science, University of Technology Sydney, Sydney, NSW 2007, Australia

Corresponding authors: Habib Ullah Khan (habib.khan@qu.edu.qa) and Mahmood Niazi (mkniazi@kfupm.edu.sa)

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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 globally distributed 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.
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 practice can be evaluated.
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.

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
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) Practitioners Experience

| RE Category   | Practice                                      | Total Frequency n=56 | Junior n=19 | Intermediate n=23 | Senior n=14 | Chi-square Test (Linear-by-Linear Association) α = .05 df = 1 X² | P     |
|---------------|-----------------------------------------------|----------------------|-------------|-------------------|-------------|-----------------------------------------------------------------|-------|
| Documentation | RD3 Include summary of the requirements        | 26                   | 9           | 11                | 6           | .056                                                            | .813  |
|               | RE3 Identify and consult system stakeholders  | 36                   | 12          | 15                | 9           | .163                                                            | .686  |
|               | RE4 Record requirements sources               | 27                   | 11          | 9                 | 7           | .042                                                            | .838  |
| Elicitation   | RA1 Define system boundaries                  | 29                   | 10          | 12                | 7           | .020                                                            | .886  |
|               | RA 5Prioritise requirements                   | 30                   | 7           | 14                | 9           | 2.655                                                           | .103  |
| Analysis &   | RA 6 Define standard templates for describing  | 28                   | 9           | 11                | 8           | .272                                                            | .602  |
| Negotiation   | requirements                                    |                      |             |                   |             |                                                                 |       |
| Description   | SM3 Model the system architecture             | 18                   | 7           | 7                 | 4           | .268                                                            | .604  |
| Modeling      | RV1 Check that the requirements document      | 28                   | 9           | 10                | 9           | .745                                                            | .385  |
| Validation    | meets your standards                           |                      |             |                   |             |                                                                 |       |
| 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                   |          |                                               |

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
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
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. RE3 (identify and consult system stakeholders), RE4 (record requirements sources) 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 | Not Known n=2 | Chi-square Test (Linear-by-Linear Association) a = .05 df = 1 X² | P   |
|-------------------|----------------------------------------------------|----------------------|--------------|---------------|---------------------------------------------------------------|-----|
| Documentation     | RD1 Define a standard document structure            | 24                   | 1            | 8             | 15               | 0               | 2.051 .152  |
|                   | RE3 Identify and consult system stakeholders        | 36                   | 2            | 15            | 17               | 1               | .861 .354  |
|                   | RE4 Record requirements sources                     | 26                   | 2            | 11            | 13               | 1               | .428 .513  |
|                   | RA1 Define system boundaries                        | 29                   | 4            | 13            | 11               | 1               | .993 .319  |
| Elicitation       | RA5 Prioritise requirements                         | 30                   | 2            | 11            | 16               | 1               | 1.592 .207 |
|                   | DR1 Define standard templates for describing        | 28                   | 3            | 9             | 15               | 1               | .732 .392  |
|                   | requirements                                        |                      |              |               |                  |                 |         |
|                   | SM3 Model the system architecture                   | 18                   | 1            | 7             | 10               | 0               | .347 .556  |
|                   | RV1 Check that the requirements document meets your | 28                   | 3            | 11            | 14               | 0               | .029 .864  |
|                   | standards                                           |                      |              |               |                  |                 |         |
| Validation        | 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 |
|-------------------|----------------------------------------------------|----------------------------------|
| Elicitation       | RE3 Identify and consult system stakeholders        | 36 Freq 64 %                     |
| Analysis and      | RA5 Prioritise requirements                         | 30 Freq 54 %                     |
| Negotiation       | RA1 Define system boundaries                        | 29 Freq 52 %                     |
| Analysis and      | DR1 Define standard templates for describing        | 28 Freq 50 %                     |
| Negotiation       | requirements                                        |                                  |                                |
| Description       | RV1 Check that the requirements document meets your  | 28 Freq 50 %                     |
| Validation        | standards                                           |                                  |                                |
| Management        | RM1 Uniquely identify each requirement              | 28 Freq 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 practices 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
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, "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                                                                 |
|------------------------|--------------------------------------------------------------------------------------------|
|                        | 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%)                                                      |
| Multinational (n=40)   | - 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%)                                                |
|                        | 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%)                                                |
| National (n=13)        |                                                                                             |

TABLE 10. Summary of findings for RQ4.

| Company Size | RE Practice critical for GSD                                                                 |
|--------------|--------------------------------------------------------------------------------------------|
|              | Following practices are identified as critical                                               |
| Small (n=8)  | - 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)| - 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) | - 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
| ID | Requirements Documents Practice                                                                 | Type of Assessment (n=56) | ID | Requirements Elicitation Practices                                               | Type of Assessment (n=56) |
|----|------------------------------------------------------------------------------------------------|----------------------------|----|--------------------------------------------------------------------------------|----------------------------|
|    |                                                                                                 | H  | M  | L  | Z  |                                                                                      | H  | M  | L  | Z  |
| RD 1 | Define a standard document structure                                                             | 24 | 22 | 9  | 1  |                                                                                      | 21 | 27 | 6  | 2  |
| RD 2 | Explain how to use the document                                                                | 16 | 22 | 16 | 2  |                                                                                      | 19 | 21 | 14 | 2  |
| RD 3 | Include a summary of the requirements                                                           | 26 | 23 | 5  | 2  |                                                                                      | 36 | 16 | 3  | 1  |
| RD 4 | Make a business case for the system                                                             | 19 | 25 | 9  | 3  |                                                                                      | 27 | 22 | 6  | 1  |
| RD 5 | Define specialized terms                                                                        | 18 | 22 | 14 | 2  |                                                                                      | 26 | 22 | 6  | 2  |
| RD 6 | Make document layout readable                                                                   | 23 | 25 | 6  | 2  |                                                                                      | 20 | 25 | 7  | 4  |
| RD 7 | Help readers find information                                                                   | 13 | 29 | 10 | 4  |                                                                                      | 23 | 19 | 11 | 3  |
| RD 8 | Make the document easy to change                                                                 | 13 | 35 | 4  | 4  |                                                                                      | 15 | 18 | 18 | 5  |
| RA 1 | Define system boundaries                                                                        | 29 | 18 | 7  | 2  |                                                                                      | 16 | 25 | 11 | 4  |
| RA 2 | Use checklists for requirements analysis                                                         | 29 | 18 | 15 | 4  |                                                                                      | 11 | 24 | 16 | 5  |
| RA 3 | Provide software to support negotiations                                                        | 10 | 17 | 23 | 6  |                                                                                      | 16 | 26 | 9  | 5  |
| RA 4 | Plan for conflicts and conflict resolution                                                       | 17 | 19 | 16 | 4  |                                                                                      | 20 | 23 | 10 | 3  |
| RA 5 | Prioritise requirements                                                                        | 30 | 23 | 2  | 1  |                                                                                      | 11 | 29 | 11 | 5  |
| RA 6 | Classify requirements using a multidimensional approach                                         | 14 | 17 | 21 | 4  |                                                                                      | 28 | 17 | 8  | 3  |
| RA 7 | Use interaction matrices to find conflicts and overlaps                                         | 7  | 14 | 25 | 1  |                                                                                      | 25 | 18 | 7  | 6  |
| RA 8 | Assess requirements risks                                                                       | 18 | 19 | 14 | 5  |                                                                                      | 19 | 26 | 9  | 2  |
| SM 1 | Develop complementary system models                                                             | 11 | 22 | 17 | 6  |                                                                                      | 12 | 17 | 8  | 3  |
| SM 2 | Model the system’s environment                                                                  | 12 | 19 | 20 | 5  |                                                                                      | 15 | 18 | 17 | 6  |
| SM 3 | Model the system architecture                                                                  | 18 | 25 | 8  | 5  |                                                                                      | 16 | 16 | 17 | 7  |
| SM 4 | Use structured methods for system modelling                                                    | 15 | 21 | 13 | 7  |                                                                                      | 17 | 15 | 7  | 7  |
| SM 5 | Use a data dictionary                                                                         | 15 | 18 | 17 | 6  |                                                                                      | 9  | 20 | 18 | 9  |
| SM 6 | Document the links between stakeholder requirements and system models                           | 13 | 18 | 19 | 6  |                                                                                      | 20 | 17 | 13 | 6  |
| RM 1 | Uniquely identify each requirement                                                              | 28 | 17 | 8  | 3  |                                                                                      | 20 | 21 | 10 | 5  |
| RM 2 | Define policies for requirements management                                                     | 17 | 19 | 16 | 4  |                                                                                      | 5  | 19 | 24 | 8  |
| RM 3 | Define traceability policies                                                                   | 17 | 18 | 14 | 7  |                                                                                      | 15 | 18 | 9  | 14 |
| RM 4 | Maintain a traceability manual                                                                  | 15 | 14 | 19 | 8  |                                                                                      | 9  | 20 | 12 | 15 |
| RM 5 | Use a database to manage requirements                                                           | 16 | 17 | 12 | 1  |                                                                                      | 16 | 15 | 14 | 11 |
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 11. (Continued.) Overall results of the empirical study.

| RM7 | Identify global system requirements | 18 | 16 | 12 | 10 | CS4 | Derive safety requirements from hazard analysis | 14 | 16 | 13 | 13 |
| RM8 | Identify volatile requirements | 11 | 17 | 18 | 10 | CS5 | Cross-check operational and functional requirements against safety requirement | 16 | 11 | 16 | 13 |
| RM9 | 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.
| ID  | Practice                                                                 | Junior (N=19) | Intermediate (N=23) | Senior (N=14) |
|-----|---------------------------------------------------------------------------|---------------|---------------------|---------------|
| RD1 | Define a standard document structure                                      | H 7 M 4 L 1 | Z 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                                                   | 8 6 3 2 8 9 6 0 4 5 5 0 |               |
| RD6 | Make document layout readable                                              | 8 8 1 2 10 9 9 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 1 4 16 3 0 5 1 1 |               |
| RE1 | Assess System feasibility                                                  | 10 6 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 1 9 12 2 0 7 4 3 0 |               |
| RE5 | Define the system’s operating environment                                  | 9 2 7 2 11 10 2 0 6 5 2 1 |               |
| RE6 | Use business concerns to drive requirements elicitation                   | 7 9 0 3 8 11 4 0 0 3 5 1 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                                 | 6 5 1 7 6 10 0 3 7 1 1 |               |
| 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 8 3 2 11 8 4 0 8 4 1 1 |               |
| DR2 | Use languages simply and concisely                                         | 7 9 2 1 7 13 3 0 8 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 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 | Develop validation checklists                                              | 7 3 6 3 5 10 6 2 5 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                                                   | 6 10 2 3 5 9 9 2 1 4 5 4 |               |
| RM1 | Uniquely identify each requirement                                        | 10 5 3 1 9 10 4 0 5 9 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 2 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 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
| ID  | Practice                                                                 | Small (N=8) | Intermediate (N=19) | Large (N=27) |
|-----|---------------------------------------------------------------------------|-------------|---------------------|--------------|
| RD1 | Define a standard document structure                                      | H 1 M 6 L 1 Z 0 8 6 5 0 1 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                               | 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 0 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 3 4 0 6 9 2 3 8 9 9 1 0 |
| 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 0 |
| 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 3 5 1 4 7 5 3 8 10 9 0 |
| SM3 | Maintain a traceability manual                                            | 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 10 9 7 1 0 |
| 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 4 3 2 1 4 2 7 10 3 9 8 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 | 9 | 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=Moderate, 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 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 out 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 managers, 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).
| ID | Practice                                                                 | Multinational (N=40) | National (N=14) |
|----|--------------------------------------------------------------------------|-----------------------|-----------------|
| RD1| Define a standard document structure                                     | H 15 5 2 0           | M 10 5 2 0      |
| RD2| Explain how to use the document                                          | M 14 3 2 0           | L 14 3 2 0      |
| RD3| Include a summary of the requirements                                   | H 16 5 2 0           | L 16 5 2 0      |
| RD4| Make a business case for the system                                      | L 16 3 2 0           | H 16 3 2 0      |
| RD5| Define specialized terms                                                 | L 17 5 2 0           | L 17 5 2 0      |
| RD6| Make document layout readable                                            | L 21 5 2 0           | L 21 5 2 0      |
| RD7| Help readers find information                                            | L 18 5 2 0           | L 18 5 2 0      |
| RD8| Make the document easy to change                                         | L 25 5 2 0           | L 25 5 2 0      |
| RE1| Assess System Feasibility                                               | H 20 5 2 0           | M 20 5 2 0      |
| RE2| Be sensitive to organisational and political consideration               | L 15 5 2 0           | H 15 5 2 0      |
| RE3| Identify and consult system stakeholders                                  | L 12 5 2 0           | H 12 5 2 0      |
| RE4| Record requirements sources                                               | L 15 5 2 0           | H 15 5 2 0      |
| RE5| Define the system’s operating environment                                 | L 17 5 2 0           | H 17 5 2 0      |
| RE6| Use business concerns to drive requirements elicitation                 | L 18 5 2 0           | H 18 5 2 0      |
| RE7| Look for domain constraints                                              | L 11 5 2 0           | L 11 5 2 0      |
| RE8| Record requirements rationale                                            | L 14 5 2 0           | H 14 5 2 0      |
| RE9| Collect requirements from multiple viewpoints                              | L 13 5 2 0           | H 13 5 2 0      |
| RE10| Prototype poorly understood requirements                                  | L 17 5 2 0           | H 17 5 2 0      |
| RE11| Use scenarios to elicit requirements                                     | L 12 5 2 0           | H 12 5 2 0      |
| RE12| Define operational processes                                              | L 15 5 2 0           | H 15 5 2 0      |
| RE13| Reuse requirements                                                       | L 9 5 2 0            | L 9 5 2 0       |
| RA1| Define system boundaries                                                 | L 11 5 2 0           | L 11 5 2 0      |
| RA2| Use checklists for requirements analysis                                 | L 13 5 2 0           | H 13 5 2 0      |
| RA3| Provide software to support negotiations                                 | L 12 5 2 0           | H 12 5 2 0      |
| RA4| Plan for conflicts and conflict resolution                               | L 14 5 2 0           | H 14 5 2 0      |
| RA5| Prioritise requirements                                                  | L 23 5 2 0           | H 23 5 2 0      |
| RA6| Classify requirements using a multi-dimensional approach                 | L 12 5 2 0           | H 12 5 2 0      |
| RA7| Use interaction matrices to find conflicts and overlaps                 | L 6 5 2 0            | L 6 5 2 0       |
| RA8| Assess requirements risks                                                | L 15 5 2 0           | H 15 5 2 0      |
| DR1| Define standard templates for describing requirements                    | L 22 5 2 0           | H 22 5 2 0      |
| DR2| Use languages simply and concisely                                       | L 17 5 2 0           | H 17 5 2 0      |
| DR3| Use diagrams appropriately                                               | L 20 5 2 0           | H 20 5 2 0      |
| DR4| Supplement natural language with other description of req.              | L 15 5 2 0           | H 15 5 2 0      |
| DR5| Specify requirements quantitatively                                      | L 13 5 2 0           | H 13 5 2 0      |
| SM1| Develop complementary system models                                      | L 8 5 2 0            | L 8 5 2 0       |
| SM2| Model the system’s environment                                            | L 9 5 2 0            | L 9 5 2 0       |
| SM3| Model the system architecture                                            | L 13 5 2 0           | H 13 5 2 0      |
| SM4| Use structured methods for system modelling                              | L 11 5 2 0           | H 11 5 2 0      |
| SM5| Use a data dictionary                                                    | L 13 5 2 0           | H 13 5 2 0      |
| SM6| Document links between stakeholder reqs and system models                | L 11 5 2 0           | H 11 5 2 0      |
| RV1| Check that the requirements document meets your standards               | L 21 5 2 0           | H 21 5 2 0      |
| RV2| Organise formal requirements inspections                                 | L 11 5 2 0           | H 11 5 2 0      |
| RV3| Use multi-disciplinary teams to review requirements                      | L 12 5 2 0           | H 12 5 2 0      |
| RV4| Define validation checklists                                             | L 15 5 2 0           | H 15 5 2 0      |
| RV5| Use prototyping to animate requirements                                  | L 7 5 2 0            | L 7 5 2 0       |
| RV6| Write a draft user manual                                               | L 17 5 2 0           | H 17 5 2 0      |
| RV7| Propose requirements test cases                                         | L 17 5 2 0           | H 17 5 2 0      |
| RV8| Paraphrase system models                                                | L 5 5 2 0            | L 5 5 2 0       |
| RM1| Uniquely identify each requirement                                      | L 20 5 2 0           | H 20 5 2 0      |
| RM2| Define policies for requirements management                              | L 14 5 2 0           | H 14 5 2 0      |
| RM3| Define traceability policies                                             | L 13 5 2 0           | H 13 5 2 0      |
| RM4| Maintain a traceability manual                                          | L 12 5 2 0           | H 12 5 2 0      |
| RM5| Use a database to manage requirements                                    | L 15 5 2 0           | H 15 5 2 0      |
| RM6| Define change management policies                                       | L 15 5 2 0           | H 15 5 2 0      |
| RM7| Identify global system requirements                                      | L 16 5 2 0           | H 16 5 2 0      |
| RM8| Identify volatile requirements                                           | L 8 5 2 0            | L 8 5 2 0       |
| RM9| Record rejected requirements                                             | L 7 5 2 0            | L 7 5 2 0       |
| CS1| Create safety requirement checklists                                     | L 12 5 2 0           | H 12 5 2 0      |
| CS2| Involve external reviewers in the validation process                     | L 15 5 2 0           | H 15 5 2 0      |
| CS3| Identify and analyse hazards                                            | L 14 5 2 0           | H 14 5 2 0      |
| CS4| Derive safety requirements from hazard analysis                         | L 11 5 2 0           | H 11 5 2 0      |
| CS5| Cross-check operational/ functional reqs against safety req.            | L 13 5 2 0           | H 13 5 2 0      |
| CS6| Specify systems using a formal specification                            | L 16 5 2 0           | H 16 5 2 0      |
| CS7| Collect incident experience                                             | L 12 5 2 0           | H 12 5 2 0      |
| CS8| Learn from incident experience                                          | L 16 5 2 0           | H 16 5 2 0      |
| CS9| Establish an organizational safety culture                               | L 10 5 2 0           | H 10 5 2 0      |

**Notes:**
- 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 subset 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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HABIB ULLAH KHAN (Member, IEEE) received the Ph.D. degree in management information systems from Leeds Beckett University, U.K. He is currently working as a Professor of MIS with the Department of Accounting and Information Systems, College of Business and Economics, Qatar University, Qatar. He has more than 20 years of industry, teaching, and research experience. He is also an active researcher, and his research work has published in leading journals of the MIS field. His research interests include IT security, online behavior, IT adoption in supply chain management, Internet addiction, mobile commerce, computer mediated communication, IT outsourcing, big data, cloud computing, and e-learning. He is a member of leading professional organizations like DSI, SWDSI, AIBIS, FBD, and EFMD. He is a reviewer of leading journals of his field and also working as an editor for some journals.

MAHMOOD NIAZI received the Ph.D. degree in the area of software process improvement from the University of Technology Sydney. He is currently working as a Professor of software engineering with King Fahd University of Petroleum and Minerals, Saudi Arabia. He has published a number of research articles in well-reputed international journals and conferences. His research interests include the areas of evidence-based software engineering, software process improvement, and global software engineering.

MOHAMED EL-ATTAR is currently working as an Associate Professor and a Chair of software engineering with Alfaisal University, Saudi Arabia. His research interests include the areas of requirements engineering, empirical evaluations, and model transformation.
NAVEED IKRAM is currently working as a Professor of software engineering with Riphah International University, Pakistan. His research interests include requirements engineering, software architecture, and empirical software engineering.

SIFFAT ULLAH KHAN received the Ph.D. degree in computer science from Keele University, U.K., in 2011. He was the Head of the Department of Software Engineering, University of Malakand, Pakistan, for three years, where he was also the Chairman of the Department of Computer Science and IT. He is currently an Associate Professor in computer science with the University of Malakand, where he is also the Founder and the Leader of the Software Engineering Research Group. He has authored over 100 articles, so far, in well-reputed international conferences and journals. His research interests include software outsourcing, empirical software engineering, agile software development, systematic literature review, software metrics, cloud computing, requirements engineering, and green computing/IT. He has successfully supervised ten M.Phil. and four Ph.D. scholars. He received the Gold Medal (Dr. M. N. Azam Prize 2015) from the Pakistan Academy of Sciences in recognition of his research achievements in the field of computer (software).

ASIF QUMER GILL is currently working as a Senior Lecturer with the University of Technology Sydney. His research interests include digital ecosystems, enterprise architecture, information security, agile methodologies, and empirical software engineering.

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