An Empirical Study Identifying High Perceived Value Requirements Engineering Practices in Global Software Development Projects

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Abstract—Requirements-related problems are reported to be the main reason in failures of global software development (GSD) projects. There is not much work done to improve requirements practices for GSD projects. In this paper, we report results of a study conducted in an ongoing project whose aim is to develop a framework for the requirements engineering process of global software development projects. The objective of this paper is to report a recent empirical study which was aimed in identifying high perceived value RE practices in the GSD projects. We used an online survey questionnaire to collect data from 39 RE practitioners of GSD organizations. We have identified 11 frequently cited high value RE practices that should be planned and implemented in GSD projects to avoid frequently occurring requirements related problems.

Keywords - ***Global Software Engineering; Requirements Engineering.***

I. INTRODUCTION

In global software development (GSD), software or part of software is developed by geographically dispersed teams and companies whereby the vendor company in one country provides its services at low costs to the client company in another country. GSD has been growing steadily and an 18-fold increase in the outsourcing of IT-enabled business processes is projected [21]. Over the last decade, many firms in Europe have outsourced software development projects to other countries such as India, China and Russia. Low cost, time saving, access to global IT talent are main reasons for software development outsourcing for the client companies [2]. Moreover, offshore vendors improve their skills and service quality with the experience of offshore outsourcing projects, learning new ways to satisfy the clients' needs.

GSD, however, has many challenges and risks [9]. Significant failure rates have also been reported in GSD projects [4]. Nam et al. [12] investigated 93 client companies and found that 36 did not intend to continue their relationships with vendors. King [10] reports that JP Morgan decided to perform many software activities that it previously outsourced, and did not renew its $5 billion contract with IBM. At the root of many failures is the increased complexity that outsourcing brings to development projects. This complexity results in: high coordination costs, information security problems, lack of direct communication [19], perceived loss of expertise in the outsourced activity [5], cultural misunderstandings [11] and infrastructure problems [1].

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 [17]. This is not surprising given that the requirements engineering (RE) process has a huge impact on the effectiveness of all software development processes [20]. A previous UK study of non-outsourced projects found that out of 268 documented development problems, requirements problems accounted for 48% of all software problems [6]. In another study of GSD projects, RE problems in multi-site software development organisations were identified [3]. The evidence is clear: problems in the requirements phase have a wide impact on the success of software development projects [6, 20] and an even greater impact on the success of GSD projects [3].

In order to improve the RE process Sommerville and Ransom [20] have suggested 66 RE practices. All of these RE practices were designed for non-GSD projects and it is hard to know if these practices can also be used in the GSD projects. Despite the importance of RE in the GSD projects, no empirical study has been conducted to observe the perceived benefit RE practices in the GSD projects.

We propose to adapt and customize these 66 RE practices specifically for GSD projects. The objective of this paper is to report a recent empirical study which was aimed in identifying high perceived value RE practices in the GSD projects. To achieve this we address the following Research Question (RQ):

RQ: Which RE practices can be effectively used in the GSD projects?

In order to address this RQ we will:

- Determine what the most important of all the RE practices advocated by Sommerville and Ransom are for GSD projects.
- Identify any additional RE practices important for GSD projects that may lack from the list of Sommerville and Ransom [20] practices.

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In earlier research works [15], we discussed preliminary results based on a pilot study with five GSD organisations. In this paper, we discuss the findings of a broader survey of 39 RE experts of GSD projects.

This paper is organised as follows. In Section II background is provided. Section III describes the research methodology. In Section IV the findings of this work are presented and analysed with some discussion. Section V describes the summary of results. Section VI provides the conclusion and future work.

II. BACKGROUND

A. RE practices designed by Sommerville and Ransom

Sommerville et al. [20] suggested a requirements framework that includes 66 requirements practices that can lead to RE process improvement and ultimately business benefits [20]. The 66 requirements 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 used typically for critical systems development. The 66 RE practices are grouped into 8 major categories [20].

Thus far, no research has considered using these 66 practices in global software development projects. Few studies have used these practices for non-outsourced projects such as [14] and [20]. It is important to identify best RE practices for GSD projects as previous work suggests that half of the companies that have tried GSD have failed to realize the anticipated outcomes, the root cause of which is often related to RE problems [17, 18].

B. Perceived Benefits.

We assert that "perceived benefits" of a particular RE practice can be used as a judgement criterion for determining the degree of importance (value) placed on a RE practice by requirements stakeholders. This is because where requirements stakeholders from different organisations perceive a RE practice as having a high-perceived or medium-perceived benefits then that practice should be considered for its importance in a RE process of GSD projects. The information about relative "perceived benefits" can help researchers and requirements stakeholders to better understand various RE practices within the GSD initiatives.

III. RESEARCH METHODOLOGY

A. Data Collection

Based on the available resources and nature of this research, we set up an online survey questionnaire to collect data from RE practitioners of GSD organizations. A pilot study was conducted with five RE experts to validate the questionnaire. We invited 150 RE experts from different software companies involved in GSD projects via emails. Basic information about the software companies was available on their respective websites. Besides request for participation, emails contained the link of the survey site. Out of 150 invitations, only 39 RE experts agreed to participate so the response rate is 26%.

Each requirements stakeholders was asked to choose and rank 66 RE practices against four types of assessments that have been developed previously [13, 20]. These assessments were:

- *High Perceived Benefits (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 Perceived Benefits (M):* This means that the practice is widely followed in the organisation's GSD process but is not mandatory.
- *Low Perceived Benefits (L):* Some GSD projects may have introduced the practice only for that project. This practice is described as 'low' perceived benefit.
- *Zero Perceived Benefits (Z):* The practice is never or rarely applied to any GSD projects.

From this list, we have the 'perceived benefit' associated with each RE practice, i.e. the degree of importance placed on a RE practice by requirements stakeholders based on their experience from previous GSD projects.

We received responses from 39 RE practitioners working in software companies involved in GSD. Participants were RE practitioners with experience ranging from 1 year (minimum) to 13 years (maximum) with average experience equal to 6 years. 70% of participants were from multinational companies. Most of the participants' companies develop business applications and data processing applications. Few participants also work in the domain of real time, safety critical and embedded systems. The majority of the participants work in large sized companies having staff sizes greater than 200.

B. Data Analysis

In order to analyse the perceived benefit of each identified RE practice, the occurrence of a perceived benefit (high, medium, low, zero) in each response was counted. By comparing the occurrences of one RE practice's perceived benefits obtained against the occurrences of other RE practices' perceived benefits, the relative benefit of each RE practice was identified. We have also used this approach to identify high and low valued RE practices and software process improvement de-motivators in our previous research [13]. For most of the data analysis, we have used statistical analysis. We believe that the presentation of data using statistical analysis is an effective mechanism for comparing and contrasting within, or across groups of variables.

IV. RESULTS AND ANALYSIS

This section is divided into 8 sub-sections, each of which corresponds to one of the eight Sommerville and Ransom categories of RE practices.

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A. Requirements Document Practice

This category has eight practices which are labelled RD1 to RD8. Table 1 shows the participant responses for this category. RD1 'define a standard document structure' is frequently cited high value requirements document practice. Because of temporal, geographical and cultural barriers in GSD, communication and coordination becomes challenging [8]. This leads to problems caused by a lack of shared understanding and other knowledge management issues. Use of predefined document structure improves shared understanding and helps the readers in reading, following and updating the document. Our results indicate that using agreed upon standard documents can assist in reducing many issues in GSD projects. RD4 'include a summary of the requirements' is also one of the frequently cited high value practices in this category. This practice can help readers of the requirements documents to get the overview of the whole requirements document.

TABLE I. REQUIREMENTS DOCUMENT PRACTICES

ID	Requirements Documents Practice	Type of Assessment (n=39)			
		H	M	L	Z
RD1	Define a standard document structure	20	13	5	1
RD2	Explain how to use the document	15	11	11	2
RD3	Include summary of the requirements	19	13	5	2
RD4	Make a business case for the system	15	18	4	2
RD5	Define specialized terms	14	15	9	1
RD6	Make document layout readable	17	16	5	1
RD7	Help readers find information	11	20	5	3
RD8	Make the document easy to change	11	21	4	3

B. Requirements Elicitation Practices

There are 13 practices in this category which are labelled RE1 to RE13 as shown in Table 2. The results show that the most common 'high' value requirements elicitation practice is RE3 'Identify and Consult System Stakeholders'. It is an interesting result as GSD system stakeholders are usually not directly available to the vendor team. They are available on the client side. To overcome this problem different tools are used ranging from asynchronous communication media (email, blogs etc.) to synchronous media (instant messaging, video conferencing etc.). System stakeholders are the domain experts and if they are not available for consultation because of different GSD barriers then the requirements related issues will not be resolved. Other most common (19 out of 39) high value practice is RE5 'define the proposed system's operating environment'. Many GSD organisations define the proposed system's operating environment during or before requirements elicitation. It is critical to determine the scope of the environment where the system will be deployed [7].

It is interesting to see in Table 2 that 12 out of 39 participants consider RE10 'prototype poorly understood requirements' as a low and zero value practice. This is not in line with the general view in RE literature about prototyping misunderstood requirements. One probable reason can be the cost and effort associated with prototyping of misunderstood requirements.

TABLE II. REQUIREMENTS ELICITATION PRACTICES

ID	Requirements Elicitation Practices	Type of Assessment (n=39)			
		H	M	L	Z
RE1	Assess System Feasibility	17	17	4	1
RE2	Be sensitive to organizational /political consideration	16	13	8	2
RE3	Identify, consult system stakeholders	27	11	0	1
RE4	Record requirements sources	16	17	5	1
RE5	Define system's operating environment	19	15	3	2
RE6	Use business concerns to drive elicitation	14	18	5	2
RE7	Look for domain constraints	18	14	5	2
RE8	Record requirements rationale	11	13	3	2
RE9	Collect reqs. from multiple viewpoints	14	19	4	2
RE10	Prototype poorly understood requirements	8	19	9	3
RE11	Use scenarios to elicit requirements	12	17	8	2
RE12	Define operational processes	15	15	6	2
RE13	Reuse requirements	9	16	11	3

C. Requirements Analysis and Negotiation

This category contains 8 practices; labelled as RA1 to RA8. Table 3 presents the participants' responses for the practices in this category. RA1 'Define system boundaries' is rated as most common high value practice. Clear definition of the system boundary early in the project helps clarify the system scope and identifying the interfaces and dependencies with other systems. Early definition of the system boundary also helps in effort and size estimation. RA3 'Use software to support negotiation' and RA7 'Use interaction matrices' are frequently cited low value practices. It seems as if they are not commonly understood and used practices in GSD projects.

TABLE III. REQUIREMENTS ANALYSIS AND NEGOTIATION PRACTICES

ID	Requirements Analysis and Negotiation Practices	Type of Assessment (n=39)			
		H	M	L	Z
RA1	Define system boundaries	20	14	3	2
RA2	Use checklists for analysis	13	12	12	2
RA3	Use software to support negotiation	6	11	17	5
RA4	Plan for conflict resolution	14	12	9	4
RA5	Prioritise requirements	19	17	2	1
RA6	Classify requirements using a multi-dimensional approach	11	12	13	3
RA7	Use interaction matrices to find conflicts and overlaps	5	10	17	7
RA8	Assess requirements risks	15	12	10	2

D. Describing Requirements Practices

This category has five practices which are named as DR1 to DR5 as shown in Table 4. The most common high value practices are DR1 'Define standard templates for describing requirements' and DR3 'Use diagrams appropriately'. The high value of DR1 corresponds well with the high value of RD1 'Define a standard document structure' described in

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section IV (A). Use of standard templates for describing requirements in GSD facilitates shared understanding and handles differences in the organizational culture. Templates help reduce the ambiguities of natural language as it poses a control and structure on the form the requirements are expressed. RE practitioners also see high value in using diagrams for describing requirements. Diagrams and models help visualize and understand requirements quickly. The high value for DR3 is indicative of the desire of RE practitioners to have a clear, common and unambiguous view of system requirements before the design and development of system commences. DR5 'Specify requirements quantitatively' and DR4 'Supplement natural language with other description of requirement' are the most common medium value practices in this category.

TABLE IV. DESCRIBING REQUIREMENTS PRACTICES

ID	Describing Requirements Practices	Type of Assessment (n=39)			
		H	M	L	Z
DR1	Define standard templates for describing requirements	19	12	7	1
DR2	Use languages simply and concisely	17	15	5	2
DR3	Use diagrams appropriately	19	10	4	5
DR4	Supplement natural language with other description of requirement	13	19	5	2
DR5	Specify requirements quantitatively	9	19	10	1

E. System Modelling Practices

This category has six practices labelled SM1 to SM6. The results show that the most common high value requirements modelling practices are SM5 'Use a data dictionary' and SM3 'Model the system architecture'. Appropriate use of data dictionary helps in removing the ambiguities and inconsistencies in the requirements document. It is also an important practice in building the same understanding of different terms, concepts and definitions. Modelling the system architecture (SM3) early is important for the realization of non-functional requirements of a system. Non-functional requirements are vital for the success of a system. We see SM3 as an important practice as it prompts the consideration of non-functional requirements on board as early as the requirements phase.

TABLE V. SYSTEM MODELLING PRACTICES

ID	System Modelling Practices	Type of Assessment (n=39)			
		H	M	L	Z
SM1	Develop complementary system models	9	15	11	4
SM2	Model the system's environment	9	15	13	2
SM3	Model the system architecture	14	17	6	2
SM4	Use structured methods for system modelling	13	14	9	3
SM5	Use a data dictionary	15	12	10	2
SM6	Document links between stakeholder requirements and system models	11	13	12	3

F. Requirements Validation Practices

There are eight practices in this category (Table 6). RV1 'Check that requirements document meets your standards' is the most frequently cited high value practice. This practice corresponds well with other similar practices in our study, i.e. RD1 and DR1. GSD practitioners believe that the compliance with standard document structure or template is important and should be ensured. RV7 'Propose requirements test cases' is another common high value practice. One of the criteria of writing better requirements is that they should be testable and verifiable. If test cases are written for requirements then this will improve the quality of the requirements. Prototyping is generally considered to be an important and useful validation technique. However, prototyping was a low value practice in the requirements elicitation section. The cost and effort associated with prototyping seem be the inhibitors of using it as an elicitation or validation technique.

TABLE VI. REQUIREMENTS VALIDATION PRACTICES

ID	Requirements Validation Practices	Type of Assessment (n=39)			
		H	M	L	Z
RV1	Check that requirements document meets your standards	21	10	5	3
RV2	Organise formal reqs. inspections	13	11	12	3
RV3	Use multi-disciplinary teams to review requirements	16	11	8	4
RV4	Define validation checklists	14	14	6	5
RV5	Prototyping to animate requirements	7	15	13	4
RV6	Write a draft user manual	13	13	10	3
RV7	Propose requirements test cases	17	12	7	3
RV8	Paraphrase system models	5	14	12	5

G. Requirements Management Practices

There are nine practices in this category as shown in Table 7. RM1 'Uniquely identify each requirement' and RM7 'Identify global system requirements' are most frequently cited high value practices. Unique identification of each requirement helps in traceability and management of all requirements. Identification of global system requirements establishes the required system level properties. They are concerned with the system architecture and should be appropriately handled in early stages of the requirements phase.

TABLE VII. REQUIREMENTS MANAGEMENT PRACTICES

ID	Requirements Management Practices	Type of Assessment (n=39)			
		H	M	L	Z
RM1	Uniquely identify each requirement	20	12	5	2
RM2	Define policies for reqs. management	16	11	8	4
RM3	Define traceability policies	16	12	5	6
RM4	Maintain a traceability manual	13	10	8	8
RM5	Use database to manage requirements	14	9	7	9
RM6	Define change management policies	16	12	7	4
RM7	Identify global system requirements	17	10	8	4
RM8	Identify volatile requirements	9	14	10	6
RM9	Record rejected requirements	7	8	16	8

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H. RE for Critical Systems Practices

There are nine practices in this category that are labelled CS1 to CS9. Most of the practices in this category have similar frequency. This category of practices seems less relevant to GSD as critical systems are usually not developed in GSD or outsource setting.

TABLE VIII. RE FOR CRITICAL SYSTEMS PRACTICES

ID	RE for Critical Systems Practices	Type of Assessment (n=39)			
		H	M	L	Z
CS1	Create safety requirement checklists	14	10	8	7
CS2	Involve external reviewers in the validation process	9	14	9	7
CS3	Identify and analyse hazards	14	10	9	6
CS4	Derive safety requirements from hazard analysis	14	12	7	6
CS5	Cross-check operational and functional reqs. against safety reqs.	16	7	11	5
CS6	Specify systems using a formal specification	11	14	10	4
CS7	Collect incident experience	12	13	9	5
CS8	Learn from incident experience	16	11	8	4
CS9	Establish an organizational safety culture.	11	15	7	6

V. SUMMARY OF RESULTS

In this section, we summarise our results and also give recommendations to RE practitioners about high perceived value RE practices which can be used in GSD projects. These high valued practices should be planned and implemented in GSD projects to avoid frequently occurring requirements related problems. Table 9 lists the most commonly cited high value practices in each category. Implementation of RD1, DR1 and RV1 will help reduce inconsistencies and ambiguities in the requirements document. It will also help to build a shared understanding of system requirements. Client and vendor organisations, being in different countries, usually have different nomenclatures. Promoting the use of standard templates will help dealing with the issues related to cultural differences of client and vendor sides. RE3 has the highest frequency count in elicitation. In GSD, vendor teams usually do not have direct access to the system stakeholders. We recommend that managers should plan to compensate for this limitation in GSD projects. GSD managers can use technology (e.g. video conferencing) or occasional visits to allow development team representative(s) to have direct communication with system stakeholders. The system boundaries (RA1) should be defined as it will help in clear definition of scope, identification of system interfaces with other systems and in project estimation and scheduling. When it comes to the requirements descriptions, we recommend that the diagrams should be used appropriately (DR3) as many concepts or processes are better explained with diagrams. This also increases the understanding of a problem domain and facilitates knowledge transfer. Use of data dictionary (SM5) is also a recommended practice for system modelling as appropriate use of data dictionary helps the readers in better understand different documents. It also avoids the inconsistent use of terms and concepts.

TABLE IX. MOST COMMONLY CITED HIGH VALUE RE PRACTICES

ID	Practice	Category
RD1 RD3	Define a standard document structure Include summary of the requirements	Documentation
RE3 RE5	Identify and consult system stakeholders Define system's operating environment	Elicitation
RA1 RA5	Define system boundaries Prioritise requirements	Analysis & Negotiation
DR1	Define standard templates for describing requirements	Description
DR3	Use diagrams appropriately	Description
SM5	Use a data dictionary	Modelling
RV1	Check that the requirements document meets your standards	Validation
RM1	Uniquely identify each requirement	Management

VI. CONCLUSION AND FUTURE WORK

To the best of our knowledge, this is the first attempt to investigate the most relevant RE practices for GSD organizations. We have identified frequently cited high value RE practices which should be used in GSD projects to avoid frequently occurring requirements related problems. We have observed that not all 66 RE best practices are perceived as high value practices for GSD projects

Our ultimate goal is to develop a framework for improving RE in GSD projects (GlobReq). The proposed GlobReq will be an easy to use framework which will be accompanied by a website and tool support to facilitate its use in industry. The aim is to help companies avoid randomly implementing promising new models and frameworks just to see them discarded.

The following two research questions are our future work in this project:

RQ1. How can we develop GlobReq?

The basis of the GlobReq framework will be Sommerville and Ransom's framework of requirements practice, empirical study with GSD organisations and our questionnaire based survey. We will collect detailed empirical data from GSD organisations and practitioners to construct and validate the GlobReq frameworks. The following initial criteria will be used for the development of the GlobReq framework. We have used this approach successfully in previous empirical research with software development organisations [13; 16].

- User satisfaction: stakeholders need to be satisfied with the results of the GlobReq framework. Stakeholders (e.g. requirements engineers, systems analysts, outsourcing project staff) should be able to use the GlobReq to achieve specified goals according to their needs and expectations without confusion or ambiguity.
- Ease of use: complex models and standards are rarely adopted by organisations as they require resources, training and effort. The structure and contents of GlobReq should be simple, flexible and easy to follow.

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- Better requirements: GlobReq should aid the development of high quality requirements (e.g. less ambiguous, more comprehensive, consistent and feasible).

Based on the empirical data, Sommerville's Requirements Framework will be rationalised to GSD environments. GlobReq framework will be developed from the rationalised Sommerville Framework together with additional empirical data collected from GSD collaborators. The frequently cited RE practices with 'high' and 'medium' perceived value' will be the basis of the GlobReq framework.

RQ2. How can we evaluate the effectiveness of GlobReq?

The evaluation of the end product is important in order to show up areas where the end product has deficits. The evaluation assists in future planning and decision making. In the evaluation process the lessons learned and results are used to enlighten future projects. We will use an expert panel review to seek the opinions of software outsourcing experts about the GlobReq framework. The criteria described in "GlobReq framework development" will be used, i.e. ease of use, user satisfaction and better requirements as the basis of this evaluation.

We will identify GSD experts for the evaluation of the GlobReq framework. These experts will be selected on the basis of their practical and/or academic experience of GSD projects. These experts will be from other organisations (i.e. not from organisations who participated in the data collection process). We have made preliminary discussions with these experts and we are in the process of explaining their role in this project.

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