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Effect of Project Management in Requirements Engineering and Requirements Change Management Processes for Global Software Development

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ABSTRACT Presently, global software development (GSD) is growing very rapidly. However, it is not an easy and straightforward process. Requirements engineering (RE) and requirements change management (RCM) both are considered as very challenging activities due to demanding rich communications. Because it is necessary to address geographical and cultural differences in GSD, this requirement makes RE and RCM challenging. This paper investigates the importance of project management in RE and RCM processes. First, the frameworks with the phenomena of specialized project management are proposed for RE and RCM. Then, a survey and blind interviews of the experts are conducted to validate the proposed frameworks. Finally, statistical tools are applied to analyze the collected data. By utilizing the analyzed data, our results show the significant impacts of both frameworks (i.e., RE and RCM) in the GSD environment.

INDEX TERMS Requirements engineering (RE), requirements change management (RCM), global software development (GSD), requirements collections (RCs).

I. INTRODUCTION

In current era, the economic and social trends boost today's businesses from national levels to global markets, and new forum initiations have been introduced. According to the last decade of research, software development in particular has witnessed an extreme revolution in its trades and processes (i.e., perceiving, designing, constructing, testing, and delivering products to end users) [1]. Now, global software development (GSD) is an intensifying trend in the software business [2]–[4]. GSD results in software organizations hiring highly expert resources at the least costs and provides the easiest approach to the customer 24/7. Hence, it also includes new tasks to handle the management of already complex software projects [5]. Distributed team members and social, cultural and time zone variances have significant impacts on

communications, work relationships and projects' success in distributed environments [6], [7].

The domain of RE is related to describing the customer's problems, determining the expectations of the customer and specifying the proposed problems' domain, which is helpful to provide the specifications to the designers to build the proposed solutions. Therefore, the process of RE has significant impacts on the effectiveness of the software development life cycle (SDLC) [8]. Poorly defined and poorly executed RE process has led to the production of low quality products [9]. Hence, the RE phase has key importance in the SDLC [9]. In the phase of RE, the communication activities between the customers and the developing organizations are very rich. The geographical and cultural differences in distributed development sites have direct impacts on all kinds

of communications. Usually, the communication is rare and more reserved in the distributed development [10]. If the developers and customers are in a distributed environment, obviously the distance affects the communications among the problem owning and problem solving. In global software development, team members address the distributed environment through different means such as email, online forums, video conferencing, phone calls and groupware etc. The identification of communication variations is very important during RE and other stages of software development. The discussed problems are not just for liner communications among team members and stakeholders but are also for problems of ongoing project management, discussions and ultimate requirements decisions made by email (i.e., the management of the RE process and the RE product). However, while the communications are very intensive in the RE process, it is still surprising that none of the RE process models have the capability to provide the systematic ways or rigorous mentions of synchronous or asynchronous tools in their process descriptions [11]–[13]. Evidently, while adopting the global software development environment, a strong framework support in the RE process is demanded for pure and quality requirements' collection and analysis.

When contrasted with the collocated software development framework, requirements change during the SDLC are very hard to manage in a globally distributed setup, such as tackling the correspondence issues regarding globally scattered team members [14]. Requirements change might be requested one or more times, but it becomes a very difficult task to manage continuous changes during software development. Ali and Lai [15] expressed that in the beginning times of software development, generally, requirements were deficient because of unclear ideas of the desired business objectives and aims. With time passing and correspondence among the stakeholders, a superior awareness of the approaching system has been obtained, and new matters have been found that should be included in the current arrangement of requirements to obtain more reliable and complete requirements. Thus, in the light of the changes in clients' demands, maximizing the awareness of stakeholders, a clear project vision, explicit requirements details and the accessibility of technological arrangements become increasingly important [16]–[21].

As per Nurmalian's [21] contextual analysis, the primary reasons for software requirements changes are modifications in user prerequisites, improving the employment of utilities, modifications in authoritative techniques, transformed designs, missing necessities, omitting repetitions and boosting prerequisites. As indicated by Alsahli *et al.* [22], requirements consistently change as a reaction to competitors in the market, changes in innovation, evolving laws, and user inclinations. Tomyim and Pohthong [23] described that change in requirements are expected since a software product needs to fulfill customers' and users' needs. Requirements change can also occur during the operational mode of a software development project or after a framework is installed and working.

It is essential to establish a reasonable comprehension about the requirements change and its effect on the total system [15], [24].

The GSD organizations that are composed of the outsourcing of different exercises (such as project planning, project administration and development) are much more meaningful and challenging for project management since the distributed development group and team members must have the capacity to interconnect with the status of the ongoing project. Information gathering, analyzing and moving to the development team in an effective way is very necessary. Furthermore, the pursuit and management of the interchange of information are also very essential for the successfully finalizing the project. A suitable framework establishes the right way to manage the information between the members of the project and among project team members and other parties that participate in the development of the project. To compensate for these functional characteristics, the results of this paper will be able to gather the correct information among organization units in the actual timeframe [25].

According to Smith and Wood [26], when producing quality software projects, there are a number of contributing factors. Perhaps the most significant factor is the nature of the developmental tasks. While in design development, the progress is noticed as a simple task since the design is shown in tangible form such as a document, which is easy to understand and handle. Although the transformation of the design into code is a complex activity and the degree of completeness is less evident, it is only checked through testing. Hence, it is necessary to assure that some measures are required to enable the project manager to assess how much the far away package is going to take complete. Therefore, the use of automated tools provides a useful situation and repeatability. However, the project manager must be a task expert [14], [16]. The project management is an inherently complex problem [27]. Usually, the plans and schedules of the project are drawn in the presence of certain various internal and external sources, especially since the conflicts in the schedule in large and medium scale projects are very common. Many unknowns have to be addressed by the software managers during the planning, software design and coding, which are highly people-oriented phases. Moreover, the software requirements usually change during the project's development, and the development tools and the platforms are not entirely stable. In the common used software project management models, various factors insist to change the requirements repeatedly and dynamically. The management of a single site software development is not an easy task, but when it is developed in a distributed environment, it becomes more difficult. Therefore, for good software management, software managers must have expertise in order to face the unknowns of internal stages' complexities [26].

For RE and RCM, the organizations need powerful frameworks, which are proven helpful for effective and efficient requirements collection and change management in GSD [14], [25], [69]. While developing the frameworks for

both RE and RCM, the issue of communication should be focused in the GSD. The analysis of existing studies discloses that there is a huge gap in the improvement of RE and RCM frameworks, which covers the situation of the GSD. As per Damian [28], GSD needs a professional RE and RCM model that reduces unfruitful data flows across the different sites, which results in complex mutual understanding and increases development revisions. Pure project management is essential for the proper implementation of frameworks, which help to manage each phase and every task of the framework in an effective and efficient way. Therefore, GSD demands frameworks for RE and RCM with expert project management. Hence, the given below study questions will address how we will accomplish the required goals.

RQ1. How is RE conducted in GSD?

RQ2. How are the requirements change handled in the GSD?

RQ3. What is the role of project management for successful RE and RCM?

A well-planned literature review will be accomplished, and the proposed frameworks (RE and RCM) will be applied in various GSD corporations to assess the objectives of this research [29].

The remaining paper is organized as; in Section II, we described the background study, Section III discussed the problem statement of work, Section IV contained the proposed work, Section V discussed the research methodologies, Section VI presented the statistical analysis, and finally section VII contained the conclusions.

II. BACKGROUND

A. BACKGROUND OF REQUIREMENTS ENGINEERING

RE in GSD deals additionally with geographic, temporal and socio-cultural distances. At the point when requirements are improperly characterized and RE procedures are poor, the final outcome will always be a weak product or a rejected project [9]. It was revealed in an industry study from the UK that just 16 percent of software projects can be considered as genuinely and successfully completed. "Usually, the poorly defined project and the codes of training are much of the time disregarded and an unhappy failure is gained from previous practices" (www.jobserve.com). Therefore, it is proven that issues in the requirement stage widely affect the accomplishment of software project improvements [30], [31]. This is a lesson that is not necessarily scholarly, in spite of the confirmation and the low measure of the exertion needed for a reliable requirement process. Numerous software products have fizzled on the grounds of meager arrangements of requirements change [8]; the condition of the business demonstrates that only approximately 60 percent of associations maintain the requirements records in a solitary warehouse, which is an exceptionally major reason in the achievement of completion and is generally anticipated by IT [32], [33]. No development procedure could meet product delivery periods, expenses and control the quality of the product if the requirements are

inadequately described and overseen [31]. However, in spite of the frequent documentation and perceived significance of RE, little work has been done on creating approaches to enhance the requirement procedures.

The Standish Group described that on average, the percentage of in-time and within budget completion of software projects has been improved from 16% (1995) to 34% (2003) [34], [35]. In modern times, the success percentages of all kinds of projects in the years 2011, 2012, 2013, 2014 and 2015 are 29%, 27%, 31%, 28% and 29%, respectively. In addition, the challenge percentages are 49%, 56%, 50%, 55% and 52% in the years from 2011 to 2015, respectively. Furthermore, the failure percentages are 22%, 17%, 19%, 17% and 19% from 2011 to 2015, respectively. However, approximately 2/3 of the projects that were examined in 2015 [30] were reported as 'challenged' (i.e., only partially successful), and the authors remarked that the main reason for project failure is unstable requirements caused by the poor management of the RE process. Several other literature studies also identified problems with the RE process [8], [29], [36]–[41]. A UK based study found that 268 total documented development problems occurred, from which 48% were issues from RE [29]. Another survey of 150 organizations was conducted in the USA, from which the majority of participants answered "None" as the requirements modeling technique [25], [42]–[45].

In the light of remarkable observations, due to the lack of an effective RE framework, 40 to 50 percent of software development efforts have to be reworked, including detecting bugs and debugging at testing level. An estimate of if a rework is necessary through project phases states that its efforts should be expanded by almost 66% in the final integration and test phases [46]. Therefore, in-time and more investment improve the project and are helpful in minimizing the rework. In a recent industrial survey, it was observed that employees demand that their hosts invest more in RE to improve the project [42]. The genuine undertaking in RE is not at a tremendous level. As indicated by Neill CJ, Laplante PA [42] approximately 5% of venture work encompasses prerequisites' exertion (elicitation, analysis, confirmation, approval, and testing), with the exception for the specification. The said work is approximately 25 percent of the total project period (or less than 90 days, but mostly it depends upon the size of the project). According to them, the system specification might take 20 to 25 percent of the total time of the project. Hofmann and Lehner [47] conducted a survey in which 15 software projects were analyzed and found that almost 16 percent of the calendar time of software projects is consumed by RE actions. A survey of 107 projects conducted by Chatzoglou and Macaulay [48] found that the requirements gathering and its analysis obtained approximately 15% of the total available time. Furthermore, according to the study of MacDonell and Shepperd [49], it was determined that without a comprehensive requirement phase or with a poor requirement phase, the chance of the successfulness of the project is very low.

MacDonell and Shepperd [49] found that in their research study of 16 software projects, there were substantial differences in the exertion levels in the project planning and requirements specification stages in their evaluation of general task exertion; as a result no examples could be described from it, aside from those without the requirements stage or with a meager requirements stage, the project was not fruitful. Sommerville *et al.* [31], [50], [51] introduced a maturity model that was obtained from already existed standards and had three levels (i.e., initial, repeatable and defined). This maturity model is useful to evaluate the existing RE models and provide a model for RE practices' valuations. The introduced model has the capability to improve the RE process models, which results in benefits to the business [50]. Beecham *et al.* [52] provided a requirements capability maturity model (RCMM) that followed the features of the Software Engineering Institute's software capability maturity model (SW-CMM). The RCMM facilitates the user to view the RE that is objective and problem-driven. This RCMM model consists of 5 maturity stages that are based on the 20 practices of RE. The practices provide a structure by connecting them to the SW-CMM at incremental levels of process maturity [29], [51], [53].

B. BACKGROUND OF REQUIREMENTS CHANGE MANAGEMENT

RCs in GSD also manage global, sequential and socio-cultural gaps [54]. Because of these variables, it hardly occurs that scattered teams are able to mutually correspond and address requirements change in GSD [55]. Changes in requirements during software development progress put the schedule, quality, and costs at risk [15]. Any change in the requirements can be a main reason for the risks and influences of the costs, software scheduling and the framework quality [56]. A survey conducted by McGee and Greer [20] revealed almost 60 different causes that are reasons for the changes in the prerequisites in a system.

Requirement management is difficult to handle because there is lack of basic knowledge and evolution in requirements. Therefore, the information has to be handled, conveyed and shared by all the scattered members to adapt to the changes in the requirements at any point during the SDLC. Deficiently dealing with changes regularly pushes a GSD team towards poor product quality and unsatisfactory technological and business outputs [24]. The communication issues [14] and RCM [28] are focused on fewer struggles in GSD than in the centralized software development framework. Low-quality change management is the major barrier in the accomplishment of software systems and the most likely reason for system failure. When a task enters the later stages of a project, obviously, it becomes more difficult to handle the changes, and the expenses of the changes increasingly affect the project [57]. Therefore, it is necessary to acquire earlier and more basic knowledge to accomplish better change management. Furthermore, the changes may bring more modifications and requirements for usefulness of

the system's mechanism, so a change influence analysis is very necessary to manage the changes [58]. It can be costly, particularly when a change is required after the delivery of the software product. As per the survey conducted for different almost 13500 software projects, the Standish Group International stated that only 29% of the surveyed software products were successful, 18% brutally failed and 53% were alleged. Requirements changes are definitely the only main cause of product failures [59].

Logical methods for requirements change management have recently received significant interest. Shameem *et al.* [60] and Garcez *et al.* [61] stated that the progression of requirements arrangements can be represented by a rotational arrangement of two stages (i.e., analysis and revision). The analysis stage checks the various desired properties of a framework that are fulfilled by its item-wise requirements conditions [62]. Significant problem-solving information is additionally provided when a reliable property is violated by the specification. At that point, the inductive learning-based [63] revision stage performs the change from the established conditions into a new condition by utilizing the problem-solving information given by the analysis stage.

A conviction modification operator is constantly described by various reasonable criteria (namely, postulates). The AGM framework [64] with its main adaptations such as the DP framework [65] supposes that the newest information is more solid. At that point, the fresh information must always be completely acknowledged in the modified result. It is submitted to the achievement postulate. As the other point of view, some purported non-organized conviction amendments [66], [67] do not figure that the fresh information must be completely acknowledged after correction. Obviously, non-organized belief modification is more proper for organizing requirements changes. Moreover, Ali and Lai presented a requirements management strategy composed of the three steps of (1) change awareness, (2) change analysis, and (3) change termination [15].

For requirement changes, the associations require the RCM structure, which must be able to viably address the change requirements [28]. With respect to the progression of the structure for RCM, the main concentration must be on the communication issues in GSD. The evaluation of the current literature reveals that no one structure of requirements change addresses the situations of GSD in a useful and capable way. RCM is uncommon in GSD, and therefore, the arrangement of these types of procedures is complicated. As indicated by Damian [28], the GSD demands an extremely effective RCM framework in light of the fact that the ineffective crosswise flow of changed data over various sites prompts challenges in communication and expanded improvement modifications. Therefore, the GSD requires a framework that empowers it to address the current communication issues and social differences and to have great project management exercises to timely address the requirement changes in globally distributed projects [68].

C. BACKGROUND OF PROJECT MANAGEMENT

To ensure the timely management of RE and RCM with limited financial resources, a superior strategy of project management is needed [48], [49]. The available tools of project management are mostly for scheduling activities [49]. Currently, there are many frameworks and tools of project management that help with the planning, estimation, tracking and control of a project, but they are not specialized for RE and RCM processes. Hence, much of their software are standalone and do not encourage a multisite work environment that demands team coordination and communication [68]. With more frameworks, the status of the project cannot be pursued correctly, and the progress and update status must be maintained by project managers using guesses or estimations [27]. Specialized project management is needed in order for global software development projects to be successful [26]. It especially occurs with multisite software projects. There is a need for precise processes to be defined in order for such projects to be well managed and tracked [27]. Furthermore, for good control and monitoring of the project, there is also the need to ensure that any deviation from the primary project plan should be controlled instantly. To adopt and produce quality software in the global software development environment, RE and RCM management play important roles [49], [68]. Towards these goals, the concept of phase-wise specialized project management frameworks (the right person or right effort at the right time and position) is provided to help address RE and RCM processes efficiently and accurately. It is flexible and easily manageable for RE and RCM phases and helps to track and solve the problems, reduce delays and costs and increase project efficiency.

As per the 2015 Standish report, the project success factors include emotional maturity at 15%, user involvement at 15%, optimization at 15%, executer sponsorship at 15%, skilled resources at 10%, standardized architecture at 8%, implementation of agile processes at 7%, modest execution at 6%, project management ability at 5%, and clear business ability at 4%. Hence, as indicated by the authors' perception, one of the major causes of the failures and instability of projects is the execution of weak project management, which is caused by ignoring the phase-wise proficient knowledge of project management (SDLC framework) [30].

III. PROBLEM STATEMENT

The current research will explore the different RE and RCM process models that are recommended by various researchers, the importance of project management, and the need of RCM framework for GSD. As described by Niazi *et al.* [44], requirement engineering framework is an efficiently useful way to obtain the pure requirements (customer expectations) and minimize the communication risks in GSD. Jiang and Eberlein [45] briefly stated that the collection of requirements in GSD is a complex task that needs an efficient process model to collect the requirements according to the satisfaction of the customers and developmental organizations. Kauppinen and Kujala [68] stated that without a proper

RE structure, the collection of pure requirements is a difficult process in GSD. Beecham *et al.* [52] stated that a proper RE framework is very helpful to collect the customers' expectations and the functional and nonfunctional requirements. According to Damian [28], in the GSD environment, a powerful framework is helpful to address geographical and linguistic problems while collecting requirements.

Nikula *et al.* [39] described that it is very hard to defeat the faced challenges without an appropriate framework of change management that occurs in GSD. Damian [28] revealed that GSD claims a stronger framework of RCM that is able to manage the requirements change effectively. Khan *et al.* [32] stated that for on-time and efficient management of requirements change in GSD, a flexible framework was proven effective. Ali and Lai, [15] stated that a systematic method needs to handle the demanded changes efficiently with an opportunity to improve the quality of the project. According to Smith and Wood [26], for the success of a project, specialized project management is very effective. According to Chan and Chung [67], to address the unseen internal complex problems, experts' project management is helpful since expertise can manage according to the nature of the module of the project.

Face to face conversations play an important role in obtaining the pure requirements and confidence of the requirement engineers and the customers. As a result, the absence of face to face (and informal) communications in GSD causes one to misunderstand the expectations of the stakeholders [70]. The key issues faced in RE and RCM due to the absence of face to face communication are [21] unclear customers' demands, incomplete requirements gathering, redundant requirements, requirements that illuminate necessary functionality improvements, and plan changes. Due to the geographically distributed environment in GSD, communication among the team members is the major problem due to temporal, social and cultural variations [55]. Compared to the centralized software development, the RE and RCM issues require more efforts while adopting GSD [14]. Due to the distributed development environment, successful project management is also challenging [5]. The Standish Group International (SGI) conducted a survey of almost thirteen and a half thousand software products in which SGI reported that 29.00 percent of products were successful, 18.00 percent products were unsuccessful and 53.00 percent software products were doubtful. The main reason for the unsuccessfulness of the products was the inefficiency of RE and RCM [34], [35], [59]. Furthermore, McGee & Greer conducted another survey in which they stated that 60 to 65 further points cause the RCs [20].

IV. PROPOSED WORK

For the proper and successful implementation of the any framework, project management plays a vital role. According to Niazi *et al.* [70] and Khan *et al.* [71] the positive impact of expert's project management is 97%. Through the review of the literature, it is determined that many project management

tools are available. However, the tools have limited scopes, unintelligent management of the unknowns and internal situational complexities in the services that make an expert project manager mandatory. This means that the expertise of the appointed project manager must match the nature of the phase of the SDLC.

Before starting the RCs, the following key points (Figure 1) should be taken into consideration by the project manager.

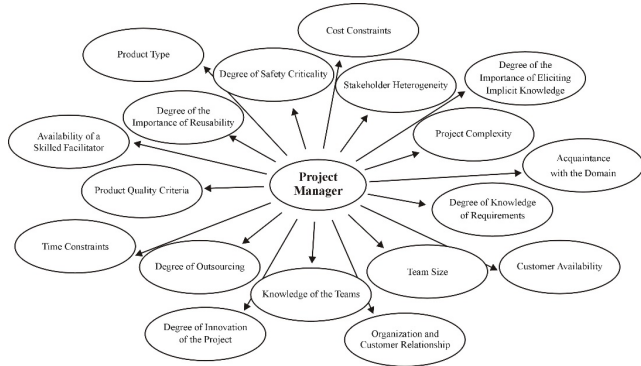


FIGURE 1. Key points for consideration by the project manager.

It is crucial to mention here that the attributes that were described can be logically connected with the characteristics of RE and RCM frameworks and methods. For example, the time limits of a project are related to the training and application costs of the RE and RCM methods. In a software project, the matter of the complexity of a product requires RC methods with high capacity in order to elicit, model, document, and verify the requirements of the project. It is insured that the performance activities of the frameworks must be correct, complete, coherent, concise, clear, considerate and courteous. The attributes of both frameworks are shown in Table 1.

A. RE FRAMEWORK

The proposed framework of RE for global software development (Figure 2) is broadly categorized into three phases. A specialized project management strategy is introduced to achieve the best objective of each phase. The first phase of the framework is the communication and documentation phase, which includes i) communications, ii) analyses and negotiations, and iii) documentation. The requirements and expectations of the customer are gathered (through interviews, site visits, document auditing, etc.), and important technical questions are asked after the analyzed requirements are documented. To manage this phase, the project manager must have customer service expertise/technical abilities, communication skills and be well versed in software terminology.

The second phase is the analyses and management phase, which includes i) validation and verification, ii) risk analyses and management, iii) tools and techniques, iv) instructions, and v) requirement management. This phase includes the different analyses activities and the procedure to manage them

TABLE 1. Abilities of the frameworks under RE & RCM.

Aspects	Sr. No.	Examples of attributes of the Techniques and Process
Technical Perspectives	FA1	Ability to facilitate communication
	FA2	Ability to help understand social issues
	FA3	Ability to help obtain domain knowledge
	FA4	Ability to help obtain implicit knowledge
	FA5	Ability to analyze and model requirements with understandable notations
	FA6	Ability to help analyze nonfunctional requirements
	FA7	Ability to facilitate negotiations with customers
	FA8	Ability to help prioritize requirements
P. M. Technicalities	FA9	Ability to manage unseen managerial problems
	FA10	Ability to manage internal technical issues of team members and projects modules
Cost Perspective	FA11	Learning curve (introduction costs)
	FA12	Application costs
	FA13	Complexity of techniques

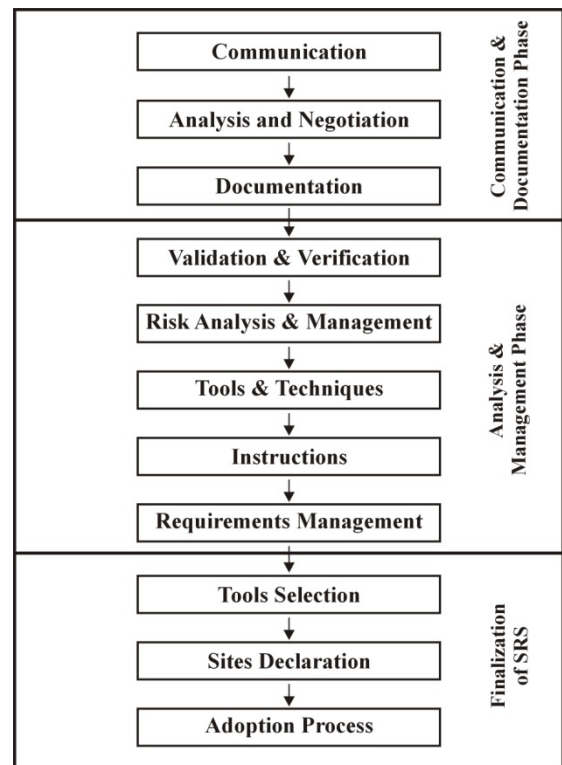


FIGURE 2. Framework of RE in GSD.

in an efficient way. Hence, the appointed project manager for this phase must have the expertise and experience to manage this type of work.

Third and last phase is the finalization of SRS, which includes the i) tools selection, ii) sites declaration, and iii) adoption of the process. Therefore, the appointed project manager of this phase must have the capabilities to manage its activities in an effective and efficient way.

B. RCM FRAMEWORK

The proposed model of RCM (Figure 3) is broadly categorized into three phases. The first phase is communication, in which requirements changes are requested by the customer. The change request becomes the initiation of the process of RCM. The detailed communication is held with the customer to obtain the data about the demanded changes. The collected data is used to identify and understand the requested changes. If the required changes are identified, then one moves to the next phase of the model. Otherwise, one returns to the data collection phase. The second phase of the proposed model is the analysis and evaluation, which contains three sub-phases. i) ‘Analysis’ is where the involved sites and the affected modules of the project are analyzed. ii) ‘Risk analysis’ is where the risks are analyzed, such as the cultural effect, the effects of team members, the effects of RC on the overall project, and the effects on the budget and the time deadline. iii) ‘Evaluation’ is where the agreements on services and policies of the best practices are evaluated. If the demands are accepted, then one moves to the next phase. Otherwise, one returns to the communication phase (data collection phase). Now, the third and last phase of the proposed model of RCM is the development and implementation, which divided into four sub-phases. i) ‘Scheduling’ is where all the activities that are necessary to develop and implement the required changes are scheduled. ii) ‘Development (coding)’ is where all the analyzed requirements are developed by the development team. iii) ‘Testing’ is applied by the quality assurance team

to check the validity of the developed module. If the quality assurance team is satisfied, then it is implemented by the associated site(s).

V. RESEARCH METHODOLOGY

To approve the systems of both the RE and RCM, interviews and overview surveys are utilized. A survey was conducted digitally and manually using a multi-sectional questionnaire to classify the elements that impact both the RE and RCM frameworks in GSD. The goal of the survey was to assess the strength of the structures and their relevant significant elements in RE and RCM as indicated by GSD professionals. We also expected to classify the function of project management in RE and RCM. The survey is a powerful technique to respond to the previously specified study questions. It can attain and assemble the experiences and views of GSD specialists all over the world [72], [73]. In addition, the survey may compute different factors at once that are acquired by the interviews of market specialists for getting detailed facts about the RE and RCM processes execution.

The purpose of empirical data collection was to evaluate the procedures of RE and RCM and the complexities being faced during the execution of the framework. An invitation to participants was sent by email. The practitioners were asked to participate on a voluntary basis and a total of 15 practitioners were interviewed. All participants were from the UK, Hong Kong, India, Pakistan, New Zealand and Thailand and had 5 to 15 years of professional experience in GSD. The interviews were conducted through meetings, phone calls, Skype voice calls and IMO calls. The experts were associated with different kinds and sizes of GSD organizations covering software solutions for various fields (e.g., business, finance, telecommunications, health, entertainment and automation technologies). All organizations were advanced GSD organizations that had multinational distributed workplaces or performed GSD by outsourcing. Requirement engineers and the relevant project managers from some renowned multinational development organizations took part in the interviews. The survey results are conferred in next section with detail.

For the survey execution, a combined questionnaire of both frameworks (RE and RCM) was developed for the online surveys and split questionnaires were developed for manual surveys. Both questionnaires (combined and split) contained the same questions and were divided into two parts: i) general information regarding the organization and the experience of the participant, and ii) questions related to the six-pointed star model (Figure 4) of project management (PMBOK 4.0).

A. DESIGN OF THE SURVEY

Targeted people for the survey were project managers, requirement engineers, analysts, program directors and key leaders associated with RE and RCM exercises in GSD. Since we are only focused on RE and RCM in a pure GSD framework, we consider just these two particular cases: i) offshore in-sourcing (various continents/states, same companies) and

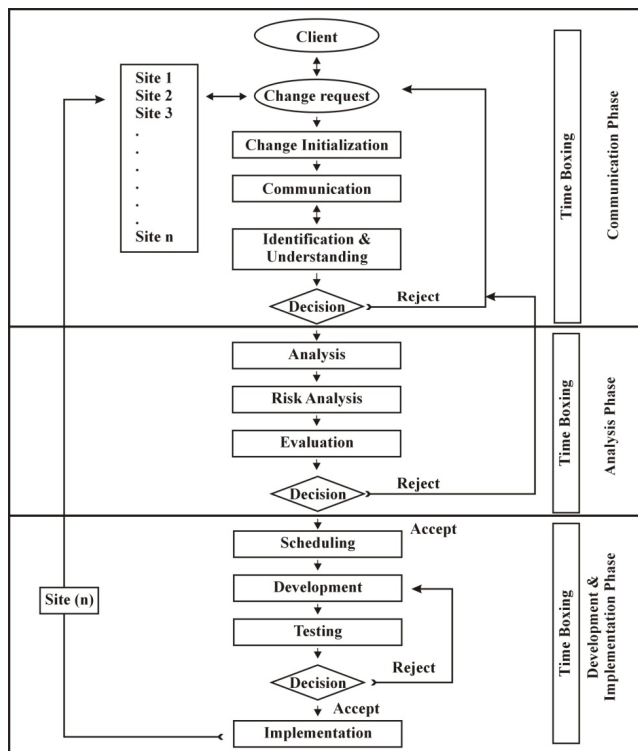


FIGURE 3. Framework of RCM in GSD.

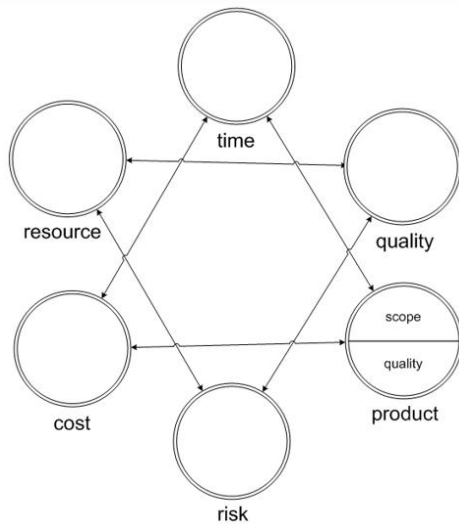


FIGURE 4. Six-pointed star model. wikipedia.org/wiki/File:TripleConstraint.jpg

ii) offshore out-sourcing (various continents/states, various companies). The targeted people were from various continents. The exponential non discriminative snowball data collection technique was utilized in the web-based survey in light of the fact that we did not know the people who were globally involved in GSD. The snowball sampling bias does not exist in this situation, and the people do not have security issues. The snowball testing procedure was conducted by sending the survey link through email to contacts in the United Arab Emirates, Sweden, Luxembourg, Australia, Germany, Pakistan, the United States of America, the United Kingdom, Finland, Saudi Arabia, Switzerland, India, and Canada.

All contact links were requested to send the link for the required survey to GSD specialists. Initially, the selected person was requested to submit the link to various persons, and those different persons were also requested to do the same. Every respondent was asked to have three more contacts on a voluntary basis, and the wave quantity was fixed to five (5). The strategy of snowball sampling was adopted by sharing the online survey link on web-based networking media (i.e., LinkedIn, Facebook and Twitter). The GSD limits communication to gatherings of GSD specialists and groups of particular GSD companies. We cannot figure out the reaction rates since we do not know about the sampling frame because of unfamiliar GSD participants.

There was a significant reason to the choose snowball sampling technique among survey design. The response rate could not be computed under the technique of snowball sampling due to the unknown number of respondents involved in the survey, similar to in a web survey [74], [75]. The concentration of the research was to assess the consequential understanding of the estimation of the reaction rate that was also reduced. A total of 46 groups on LinkedIn and 14 groups on Facebook were connected and requested to ask their members to take part in online survey. A vast number of

emails were sent to those persons who are working in GSD that were recognized from web. For manual data collection and deep study, the proposed frameworks were executed in seven (7) GSD organizations. Well-designed questionnaires for data collection were given by email to the participants while implementing the frameworks.

B. SURVEY INSTRUMENTS

The questionnaire consisted of 24 queries. The survey questions evaluated information on an ordinal basis and minimal scale, where a 5-point Likert scale was utilized from “strongly agree” to “strongly disagree” for the ordinal information. The “neutral” in the questionnaire was utilized for trouble-free analysis. The questionnaire components were collected on the basis of the literature and then piloted for understanding, un-ambiguity, and fulfillment. The survey questions were constructed to meet the goal of the research. The survey questionnaire consisted of 2 major segments. The second segment was additionally isolated into 7 sub-segments (the six-pointed star model (PMBOK 4.0) and one section with the heading of project management) as shown in Figure 4, where it was linked with the useful exercises of RE and RCM structures. The survey also included a cover letter stating the objectives and benefits of the survey and a statement to ensure the respondent’s privacy and secrecy. The testing was conducted as a 2-stage procedure. Initially, it was forwarded to study specialists of the relevant field. A few modifications were suggested during this stage. After incorporating the suggested modifications, the questionnaire was forwarded to a relevant project manager of a software development organization while finalizing the testing stage. The said GSD organization is certified by ISO-9001 and spends significant time in web-based frameworks for global customers. The said organization has worldwide setups in Germany, United States and Finland and various worldwide business partners. Established in 2000, the said company has 200+ workers. The survey was additionally tested subjectively by the same company to confirm the concepts and incorporated changes of the survey questionnaire. The examining strategy for psychological testing was utilized. The survey also asked questions associated with understanding, recovery, judgment, and reaction. No main modifications were needed after the testing criticism. After the testing feedback, it was suggested to insert details into a few questions for improved understanding.

C. SURVEY EXECUTION

For the survey’s execution, two approaches were adopted: the i) web-based survey and ii) the manual survey. The purpose of the web-based survey was to collect the general views of the respondents regarding the proposed frameworks and the manual survey was to collect the real views after the implementation of the proposed frameworks. The proposed RE framework is implemented in 4 GSD organizations, and the RCM framework is implemented in 5 GSD organizations.

Therefore, the questionnaire was uploaded for the online survey in October 2017, and it was operational for almost two and a half months. The manual survey was conducted from October 2017 to January 2018. We would like to note that with overwhelming constancy, we obtained 93 responses from the web-based survey, out of which only 24 were useable. Through the manual survey, a total of 63 responses for RE were collected, out of which 29 were useable. In addition, a total of 71 responses for RCM were collected, and 26 were useable.

We rejected the responses given by universities researchers because we did not know about their working experiences in software development industries. The reactions were arranged continent-wise, as in Figure 5 for the web-based survey, in Figures 6(a&b) for the physical-based survey, and Figure 7 for the interview participants who experienced both frameworks. We gathered data with respect to the participant's nation to make clear that we have participants from all over the world.

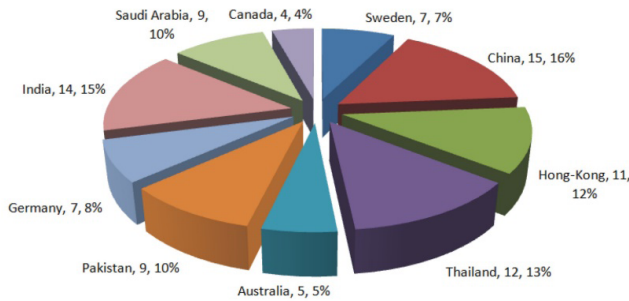


FIGURE 5. Continent-wise web survey responses from the RE and RCM frameworks.

VI. STATISTICAL ANALYSES

According to the second part of the survey questionnaire, factor wise data was collected. After applying the statistical tools and techniques, the results were finalized. Thus, the Likert scale is categorized into three phases: a) strongly agree + agree, b) neutral, and c) strongly disagree + disagree. For presenting the results, only part a) will be used, which shows the respondents' opinions about each factor of the frameworks.

A. RESULTS OF THE RE FRAMEWORK

1) WEB-SURVEY RESULTS ABOUT THE RE FRAMEWORK

The web survey results of the proposed RE framework are presented in Figure 8. According to the analyzed results, the RE framework with specialized project management is very effective for collecting the pure and complete requirements. The effect of the proposed framework on all factors regarding the six-pointed star model of project management is very significant. According to the factor-wise significance level of the proposed framework, the factors are arranged in the following decreasing order: scope factors, quality factors, risk factors, budget factors, resource factors,

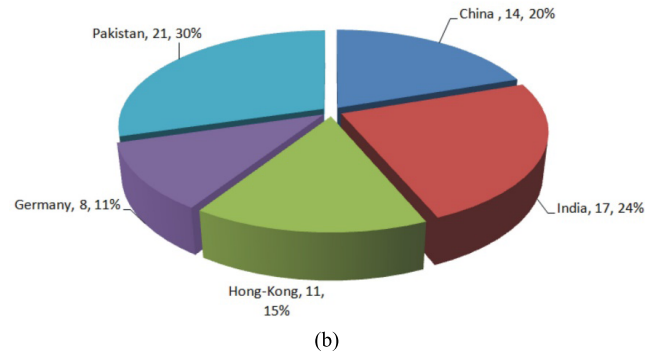
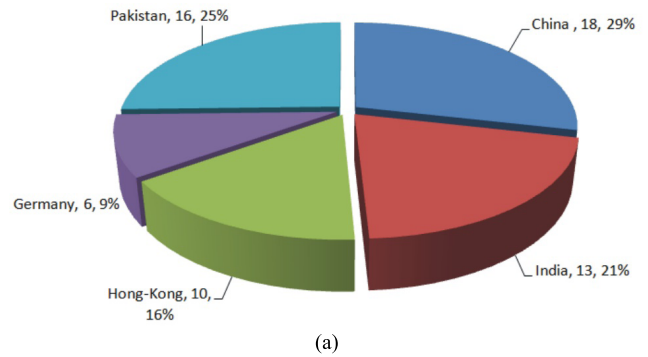


FIGURE 6. (a) Continent-wise manual survey responses for RE. (b) Continent-wise manual survey responses for RCM.

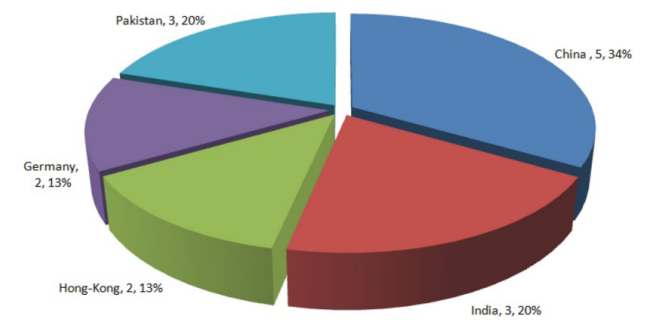


FIGURE 7. Continent-wise interviews participants for RE and RCM.

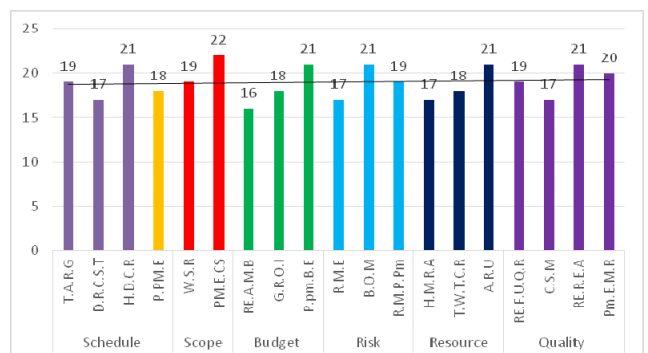


FIGURE 8. Frequency analysis of the web-survey of the RE framework.

and scheduling factors. Therefore, the trendline shows that all the factors are highly significant for the proposed RE framework.

2) MANUAL SURVEY RESULTS ABOUT THE RE FRAMEWORK

As stated earlier, the manual survey was conducted after the proper implementation of the proposed framework in four (4) GSD organizations. It is the interest of the researchers that the survey respondents are active participants in the implementation of the proposed framework. Therefore, the manual survey results of the proposed RE framework are presented in Figure 9. According to the analyzed results, the RE framework with specialized project management is very effective for collecting the pure and complete requirements. The effects of the proposed framework on all factors of the six-pointed star model of project management are very significant. According to the factor-wise significance level of the proposed framework, the factors are arranged in the following decreasing order: quality factors, risk factors, schedule factors, budget factors, resource factors and scope factors. Therefore, the trendline shows that all the factors are highly significant for the proposed RE framework.

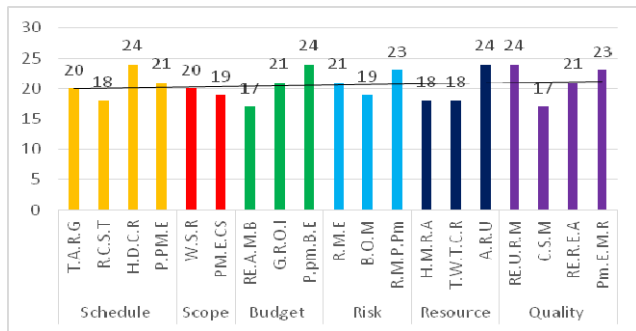


FIGURE 9. Frequency analyses of the manual survey of the RE framework.

3) BLIND INTERVIEW RESULTS ABOUT THE RE FRAMEWORK

To analyze the significance of the proposed RE framework, blind interviews of the experts were conducted. During the interviews, technical questions were asked, and the answer data were recorded. Therefore, based on analysis of the collected data, Figure 10 is presented. The trendline shows that the proposed RE framework performs well for all the factors of the six-pointed star model. According to the factor-wise significance level of the proposed framework, the factors are arranged in the following decreasing order: scope factors, schedule factors, risk factors, resource and quality factors (which are equal) and budget factors.

4) COMPARISON OF THE RESULTS OF THE WEB SURVEY, MANUAL SURVEY AND INTERVIEWS

Figure 11 shows the factor-wise comparison of the web survey, manual survey and interviews. According to the graphical representation, the responses for the schedule factors are highly correlated, which represents that the schedule factor of the RE framework is positively effective for the RE process. Just as with the schedule factors, the responses for all the other factors are also highly correlated. In contrast

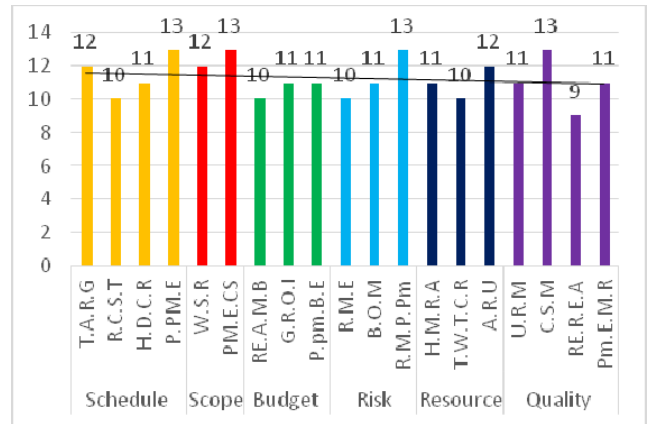


FIGURE 10. Frequency analyses of the interviews of the RE framework.

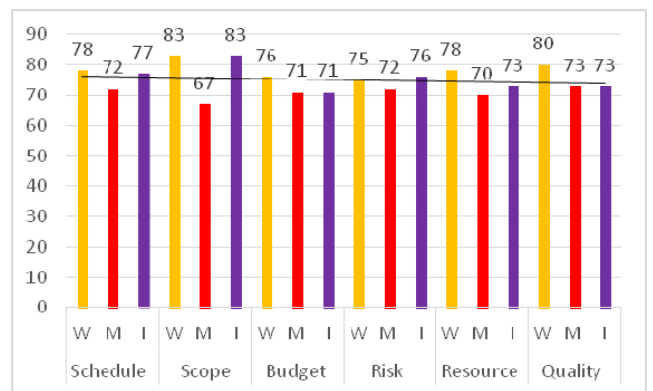


FIGURE 11. Comparison of the web survey, manual survey and interviews.

to the manual survey responses, the results of the manual survey for the scope factors are correlated but not highly correlated.

B. RESULTS OF THE RCM FRAMEWORK

1) WEB SURVEY RESULTS ABOUT THE RCM FRAMEWORK

The web survey results of the proposed RCM framework are presented in Figure 12. According to the analyzed results, the RCM framework with specialized project management is very effective for managing the required changes during

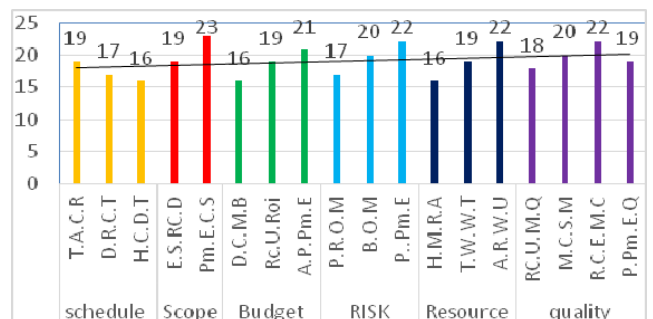


FIGURE 12. Frequency analyses of web survey.

development. The effects of the proposed framework on all factors of the six-pointed star model of project management are very significant. According to the factor-wise significance level of the proposed framework, the factors are arranged in the following decreasing order: scope factors, quality factors, risk factors, resource factors, budget factors and scheduling factors. Therefore, the trendline shows that all the factors are highly significant for the proposed RCM framework.

2) MANUAL SURVEY RESULTS ABOUT THE RCM FRAMEWORK

As stated earlier, the manual survey was conducted after the proper implementation of the proposed framework of RCM in five (5) GSD organizations. It is the interest of the researchers that the survey respondents are active participants in the implementation of the proposed framework. Therefore, the manual survey result of the proposed RCM framework is presented in Figure 13. According to the analyzed results, the RCM framework with specialized project management is very effective for managing the demanded requirements changes. The effects of the proposed framework on all the factors of the six-pointed star model of project management are very significant. According to the factor-wise significance level of the proposed framework, the factors are arranged in the following decreasing order: quality factors, resource factors, budget factors, risk factor, scheduling factors and scope factors. Therefore, the trendline shows that all the factors are highly significant for the proposed RCM framework.

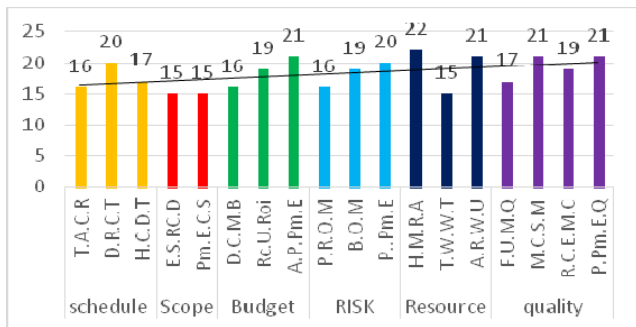


FIGURE 13. Frequency analyses of the manual survey.

3) BLIND INTERVIEWS RESULTS ABOUT THE RCM FRAMEWORK

To analyze the significance of the proposed RCM framework, blind interviews of the experts were conducted. During the interviews, technical questions were asked, and the answered data were recorded. Therefore, based on analysis of the collected data, Figure 14 is presented. The trendline shows that the proposed RCM framework performed well for all the factors of the six-pointed star model. According to the factor-wise significance level of the proposed framework, the factors are arranged in the following decreasing order: scope factors,

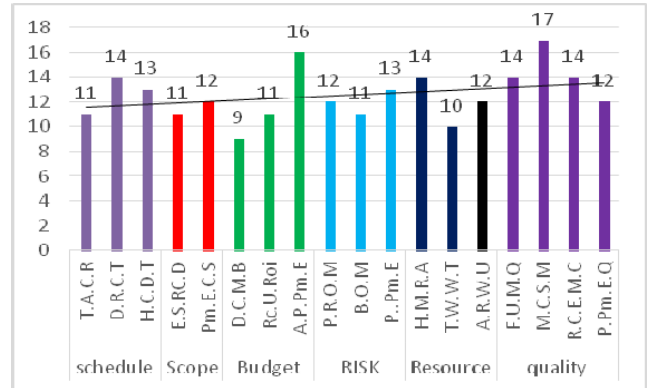


FIGURE 14. Frequency analyses of the interviews.

schedule factors, risk factors, resource and quality factors (which are equal) and budget factors.

4) COMPARISON OF THE WEB SURVEY, MANUAL SURVEY AND INTERVIEWS OF THE RCM FRAMEWORK

The comparison of the web survey, manual survey and interviews is presented in Figure 15. According to the presented figure, the computed results of all the factors are highly correlated, except for the scope factors. The scope factors are not considered as highly correlated but can be considered as correlated. The correlation of the data collected from different sources is the evidence that all of the factors of the RCM frameworks perform well.

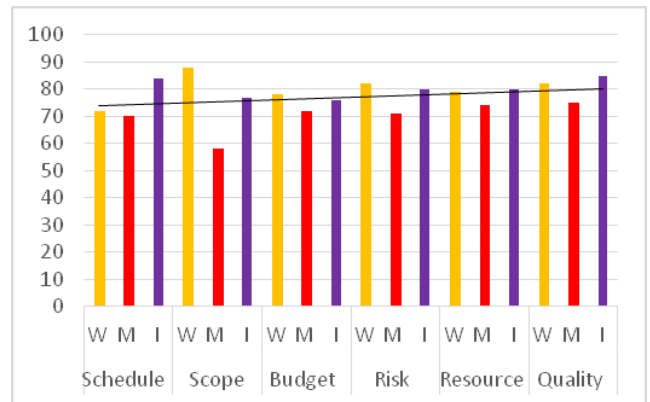


FIGURE 15. Comparison of the web survey, manual survey and interviews of the RCM framework.

C. EFFECT OF PROJECT MANAGEMENT

The results of the survey are as follows.

- 1) The phase-wise appointment of a project manager is an effective activity for the on-time delivery of a project.
- 2) The expertise of the project manager is important for managing the internal unknowns and complexities.

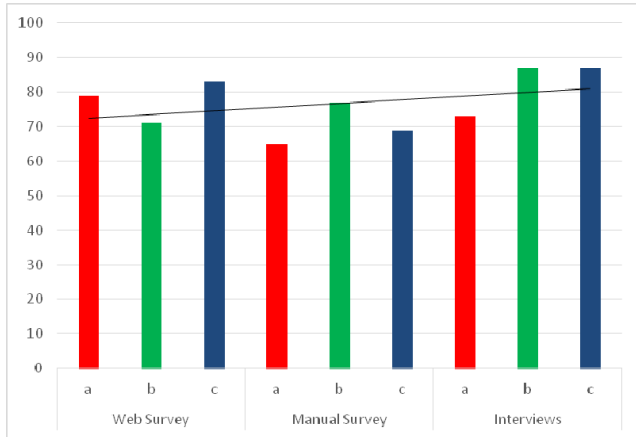


FIGURE 16. Effects of project management through the web survey, manual survey and interviews.

- 3) The involvement of phase wise experts in a GSD environment is very helpful for handling the geographical differences, language differences, time zones, etc.

The results of the “effect of phase-wise specialized project management” in RE and RCM are evaluated by utilizing the data collected from all resources, which is presented in Figure 16. The presented results describe the significant response from the respondents of all data sources. The significant response shows the importance of specialized project management for RE and RCM. We believe that if the

phase-wise specialized project management technique is applied in both frameworks, the activities of RE and RCM will have good results, which leads to better quality product and an increased project success rate.

VII. CONCLUSION

In software development, complete and pure requirements collection and requirements management are important and very complex activities in the SDLC. However, in a GSD, RE and RCM need to additionally address geographical, temporal and socio-cultural distances. Communication is a very rich and native activity in RE and RCM processes. Hence, there is a dire need of a specialist project manager to address the issues efficiently and effectively in each process. This study provides the frameworks for both RE and RCM having the phenomena of specialized project management. The proposed frameworks are categorized into three main phases in such a way that each phase has a specific task. Thus, there was a dire need for a specialist project manager to address all three phases accurately and efficiently. To validate the frameworks, surveys and interviews were conducted, and the collected data were analyzed by utilizing statistical tools. The analyzed results revealed the significant impacts of the proposed frameworks by adopting the phenomena of specialized project management.

APPENDIX (QUESTIONNAIRE)

See Sections 1–3.

Section 1: Respondent’s personal detail

- Gender** Male Female
- Position in the organization**
 Requirement Engineer Coder Designer Analyst Tester
 Project Manager CEO other
- Level of education**
 Ph.D Master Undergraduate Diploma Others
- Which Software development methodology is used**
 Lightweight Heavyweight
- Overall Experience of working by using this model**
 1-2 Projects 3-8 Projects 8-20 Projects More than 20
- How many software development professionals are working in your organization?**
 Less than 10 10 to 49 50 to 250 More than 250
- Which factor is most important for you as a professional when adopting a method?**
 Low cost Easy to handle Great productivity
 Great reliability Do not know
- What type of applications, does your organization work on?**
 End user applications Desktop applications Web based applications
 Safety critical applications Distributed applications Mostly 2 and 3
- Specialization of project manager effects**
 Very low Low High Very high Don’t effect
- The used model is well confident for requirements change management process in GSD environment?**
 Strongly disagree Disagree Neutral Agree Strongly Agree

Section 2: Respondent’s opinion about the Framework of software requirements change management

		QUESTIONS	SD	D	N	A	SA
SCHEDULING	11.	Team members are timely aware about demanded requirements changes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	12.	The demanded requirements changes are collected timely and satisfactory.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	13.	Requirements change management process is helpful to in-time implementation of demanded changes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SCOPE	14.	The impact of demanded changes on the project is well-defined.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	15.	PM methodology is effective to make the clear scope of demanded changes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BUDGET	16.	The demanded changes are managed within budget	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	17.	The management of required changes is useful for good Return on Investment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	18.	Appointment of phase-wise project/software manager is useful to manage the budget	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RISK	19.	Risks and opportunities in requirements change management process are managed effectively and efficiently.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	20.	The management of requirements changes is helpful to meet the business objectives	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	21.	The appointment of phase-wise expert project/software manager’s is useful to minimize the risk.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESOURCES	22.	Human and material resources are mostly available while implementation of requirements change management process	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	23.	Team members can work together to manage the demanded requirements changes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	24.	The available resources are maximum utilized while requirement change management process	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
QUALITY	25.	The process of requirements change management is useful to meet Quality requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	26.	Client satisfaction is met by adopting the process of requirements change management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	27.	Requirements change management is an effective activity for success of the project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	28.	The phase-wise expert project manager’s involvement is useful to manage the demanded requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PROJECT MANAGEMENT	29.	Phase-wise appointment of project manager is an effective activity to manage the demanded changes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	30.	Expertise of project manager is important for managing the internal unknowns and complexities while implementation of requirements change management process in the context of GSD.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	31.	The involvement of phase wise experts in GSD environment is very helpful for dealing the geographical differences, language differences and time zone differences while requirements change management process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any Additional Comment							

SD=Strongly disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly agree

Section 3: Respondent’s opinion about the Framework of software requirements change management

		QUESTIONS	SD	D	N	A	SA
SCHEDULING	32.	Team members are timely aware about purpose of requirement collection	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	33.	The demanded requirements are collected satisfactory from the customer timely	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	34.	Helpful to deliver the complete and pure requirements on time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	35.	Phase wise project management is an effective activity for in time collection of compete requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SCOPE	36.	The scope of requested requirements is well-defined	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	37.	PM methodology is effective to collect the pure requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BUDGET	38.	The Requirement engineering activities are managed within budget	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	39.	The requirements collection procedure is useful for good Return on Investment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	40.	Appointment of phase-wise project/software manager in requirement engineering is useful to manage the budget	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RISK	41.	Risks and opportunities in requirements engineering process are managed effectively and efficiently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	42.	The collected requirements are meet the business objectives	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	43.	The appointment of phase-wise expert project/software manager’s is useful to minimize the risk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESOURCES	44.	Human and material resources are mostly available while requirement engineering process	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	45.	Team members can work together to collect the pure requirement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	46.	The available resources are maximum utilized while requirement engineering procedure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
QUALITY	47.	Requirements engineering framework is useful to meet the quality requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	48.	Clint satisfaction is met by adopting the requirements engineering procedure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	49.	Proper requirements engineering framework is an effective activity for the success of the project	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	50.	The phase-wise expert project manager’s involvement is useful to collect the pure requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PROJECT MANAGEMENT	51.	Phase-wise appointment of project manager is an effective activity for in-time delivery of project	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	52.	Expertise of project manager is important for managing the internal unknowns and complexities while requirements engineering	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	53.	The involvement of phase-wise experts in GSD environment is very helpful for dealing the geographical differences, language differences and time zone differences while requirements engineering procedure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any Additional Comment							

SD=Strongly disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly agree

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