Environmental Factors Influencing Requirement Engineering in Global Software Development: A Review

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Abstract— **Today's software organizations have to operate in an environment which is highly networked. With this it has an increase concern not only for integrating various technologies but also for economic, environmental and social aspects. Environmental factors are considered to be very influential while performing requirement engineering (RE) process in global software development (GSD) paradigm. Our focus in this study is towards environmental aspects of RE in GSD paradigm where the teams are geographically distributed from each other. In specific we want to explore the environmental factors which may impact the software RE process in GSD paradigm. The information used for this identification is taken from the literature by performing systematic literature review (SLR). In order to have unique identification of each of the environmental factor, Grounded theory's constant comparison and memoing steps are adopted. The initial list of environmental factors may leads to progressive enhancement for assisting in RE activities in GSD paradigm.**

Keywords— **Environmental factors, Global Software Development (GSD), Requirement Engineering (RE), Systematic Literature Review (SLR).**

I. Introduction

RE process comprises of five activities: requirements extraction or elicitation, requirements analysis and design, requirements specification, requirements validation and requirements management [1, 4, 5]. If we make it more general than basically RE process consists of two main processes which are requirement development and management. Where Requirements development deals with all the activities related to requirements elicitation or extraction, analysis and validation [2,3,6] and requirements management comprises of all the activities which are indulge not only in producing changes in requirement baseline request but also involve in performing change request analysis, approving or not approving the changes and implementing approved changes.

In large scale software development, RE is considered to be the most important activity as it greatly impacts the project success and failure [7]: these large scale projects consist of distributed teams who work together for software project development. Quality RE process acts as a baseline among distributed teams and presents a foundation for other software development activities. It is reveled from the past century's last decade and from the 21st century that there are new characteristic features related to large scale systems from industry and non industry. Today's software organizations have to operate in an environment which is highly networked. With this it has an increase concern not only for integrating various technologies but also for economic, environmental and social aspects. There are number of studies, which focus on the factors affecting software RE process. Michael G et al. [9] focus his study on three contexts: organization, environment and project. In their study, they depict the necessity of RE process to consider these contexts in order to have a quality outcome. It has been argued in the previous research that the environment has a strong influence on RE process [10].

Our focus in this study is towards environmental aspects of RE in GSD paradigm where the teams are geographically distributed from each other. In specific we want to explore the environmental factors which may impact the software RE process in GSD paradigm. The information used for this identification is taken from the literature by performing systematic literature review (SLR) [11]. In order to have unique identification of each of the factors generating risks, Grounded theory's [12] constant comparison and memoing steps are adopted.

The rest of the paper is structured as follows. Section II describes the background of the study, section III illustrate the methodology of the study, section IV comprises of results, section V consist of discussion and section VI is the conclusion of the study.

II. background

Requirements engineering is a process in which multiple people group together and come up with a valuable solution. It

is not surprising that RE is having a lot of importance in success and failure of projects. Some researchers say that it is important to detect the RE phase defects with in the phase, as if the defects are captured, when the system becomes operational then the defects cost will be 10 to 200 times more [13, 14]. Similarly there are some more researchers who focus on the importance of the RE activity by saying that the reworking requirements accounts for 40 to 50% of complete project effort [15]; the RE estimated defects are more than 50 %. So it is evident from the previous studies that RE phase should be performed in great care as it causes number of undesirable phenomena like: over budget project, poor quality application, after delivery the products are not used significantly [16].

Now days we have an additional problem that the RE environment has changed, which added an aspect of complexity. Today's the tasks for software development takes place in an environment which is dynamic, which results in interchangeable and ambiguous requirements. These changes can be stimulated by various factors. Researchers have focused their attention towards these factors which are related to environment and say that, these environmental factors have greater impact on RE activities; "The process for eliciting the work-group and end-user requirements are premised on the notion that sound and accurate descriptions of the users and their environment is at first necessary." [17].

It is further elaborated by researchers that the environmental factors constrains can be related to hardware and software, domains maturity, domains interfaces certainty and role of target system [9]. Similarly researchers have also discussed the environmental constrains in their studies and say that environmental constrains are the one which restrict requirement engineer to properly analyze the requirements. Besides this the author says that these type of constrains have a strong impact on requirements elicitation process; "performing requirements analysis for an application area may require specific methods and tools that are not necessary for other types of application." [18]. Researchers defined environmental factors as ''factors that characterize a project and its environment'' [19] and a number of work has been done in this area [19–20]. Four prime categories are identified by Xu and Ramesh [19]: Project, Team, External Stakeholders, and Organization, but these categories cover the software development process in general. These further consist of twenty software factors such as size and type of project and personnel turnover. They also come up with a model base on software tailoring and argue that any change in the software process can results in environmental change and vice versa for the environmental change that, any change in environment can change the software process. Similarly some other researchers also focus their work on factors which can impact software development. They surveyed the research literature on this topic from the period of 1996-2006, and their main focus was on empirical analysis. So they identified the factors which can impact the software projects outcomes [21]. We have come to know that number of researchers have talked about environmental factors such as features of the system environment (lack of fit of the system with users, operational environment), features of the system development

environment (cognitive and skill limitation) and external business environment. Factors identified by the researchers, no matter offers a considerable strength of information but it is general to the whole software development process and does not talk about the influence of these factors at activities level.

III. RESEARCH METHODOLOGY

In our attempt to review, we pursue the method mentioned in [11]. The goal is to identify the environmental factors which may influence the RE process in GSD paradigm.

RQ1: What are the environmental factors which may influence the RE process in global software development (GSD)? Keywords for the search are: RE (RE), Software, Global Software Development (GSD), and Environmental factors.

The selected sources are: ACM Digital Library, Emerald, IEEE, Springer-Link, Science Direct, Wiley online and JSTOR. The queries for the research question are: **Q1:** '((software "requirement engineering") AND ("distributed development")) AND (environment)', **Q2:** '((software "requirement engineering") AND ("global development")) AND (environment)', **Q3:** '("Environmental Factors") AND (software "requirement engineering")'.

Besides this the inclusion and exclusion criteria consists of three levels. At first level papers which are either table of contents or some information about the conference and workshops full proceedings etc are excluded. At second level papers are checked on basis of keywords. So if the paper lack the keywords ("requirement" OR "requirement engineering") AND ("environment" OR "environmental factors"), then it is excluded from the dataset. In the last level exclusion is done base upon repetition; every repeated paper is included once.

The initial data sets (papers) are established besides with their filtration on basis of inclusion and exclusion criteria. From ACM we got (4) papers, similarly from Emerald (6) papers, IEEE (4) papers, JSTOR (0) papers, Willey online (16) papers, Science Direct (22) papers and Springer Link (18) papers.

IV. RESULTS

The extraction of the data units is taken place from the literature. These identified data units as shown in Table I are the environmental factors, which may influence RE process in GSD paradigm. These environmental factors are then gone through a process of filtration for identification of unique list of factors. The filtration here is done on basis of conceptual and explicit duplications. The data coding, constant comparison and memoing techniques of Grounded theory are used in order to get unique factors [12, 22, 23]. Therefore data is scanned against duplication instances. Preservation of source information is necessary while joining data units. This joining can be done at two levels i.e. explicit duplication level and conceptual duplication level. In both cases the rule for source preservation is applied and memos are generated.

TABLE I.   ENVIRONMENTAL FACTORS

Factors	Sub-Factors	References
Organization	Strategies, Standard, Criteria, Tasks, Process, Culture, Power relation, Trust, Learning exposure, Incentives, Politics, Tools, Techniques, Resources, Practices, Technical maturity, Economic maturity, Funding	[24,25,26,27,28,32,33,36,38,40,41,42,43,44,50,53,54,58,59,61]
Relationship	Management relationship, Customer relationship, Trustworthiness, Mutual understanding	[39, 49]
Compatibility	Tools, technologies	[24,35,36,38,40,41,43,51,53,57,58,61]
Evolution	Technology advancement, Arrival of new rival, New regulations and de-Regulations, Change adaptability	[24,31,32,39,54,55]
Constraints	Project specific constrains, Governmental constrains/actions, Working conditions, Organizational constrain, Environmental constrain	[29, 32,33,34, 38,42,43,46,52,56, 57,60]
Multiplicity	Roles, Activities, Artifacts	[56]
Staff	Motivation, Experience, Knowledge and skill, Control & reward, Professional obsolesce, Family responsibilities, Work family conflict, Family and friend support, Perceived job alternatives, Situation recognition, Workspace awareness, Learning difficulty, Performance, Familiarity with tools and techniques, Job type, Job security, Carrier stage, Historical context	[27,29,31,33,36,37,40,41,43]
Workplace context	Working atmosphere, Operational aspects, Workspace atmosphere, Organization business climate, Location/ distance	[28,29,30,31,35,38,42,43,45,54,56,57]
Tasks	Properties, Complexity, Project risk, Interaction mode, Time interval, Process models	[25,27,36,40,42,47]
Cultural and social aspects	Values, Social interactions, Language Socio cultural aspects of workspace, Socio cultural aspects of work organization, Community norms	[32,35,36,38,41,50,54,59,61]

Once the duplication is removed then the factors are labeled and sub- factors are grouped. Reason and justification of labeling and grouping are maintained in memos. If changes are occurred related to shifting to any sub-factor to any other factor or some novel factor then the labels are renamed if required. Here also we preserve their sources. The initial list of environmental factors is then forwarded to experts from academia for evaluation. Experts are selected base upon their expertise in RE field and are also specialized in RE (PhD).

The experts recommended some modification in the initial list of environmental factors. For example: Sub-factors of "Organization" are recommended to have following changes: *standard* and *criteria* are asked to be mentioned separately in the list, due to their distant meanings. Similarly sub factor *economic aspects* are recommended to change to *economic maturity.* For factor "Staff" following modifications is recommended: sub factor *knowledge* is recommended to combine with *skills.* Similarly sub factor *qualification* is recommended to drop from the list as it has same logical meaning with *knowledge and skills.* For factor "Workplace Context" following modifications is recommended: sub factors *Location* and *distance* are recommended to be separately mention in the list due to having different meanings. For the factor "social and cultural aspects", reviewers gave following recommendation: sub factors *socio cultural aspect of workplace* and *socio cultural aspect of work organization* are recommended to have different names, as according to the reviewers, the factors and sub factors names should be distant from each other. So instead of these two factors, four new factors are added in the list: *workspace societal aspects*, workspace *culture*, *work organization societal aspects* and *work organization culture*.

In total, after expert reviews 10 factors and 69 sub-factors are finalized as shown in TABLE I. These factors are the environmental factors which can effect RE process in GSD environment. The consideration of these factors and sub-factors would result in successful RE process in GSD.

V.   **discussions**

In this section, contribution, future work and limitations of our study is discussed in detail.

A.   *Contribution*

The identified environmental factors which may influence RE process in GSD paradigm can be consider as an important reference for researchers, whose concerning areas are in software RE, as it consist of the initial list of environmental factors which may influence RE directly or indirectly in GSD paradigm.

The initial list can also proceed as guidance for the researchers and practitioners working in RE, to consider and control these factors in order to have quality RE process in

GSD paradigm. Besides with the initial list of factors, this work also contributes in listing the sub factors which actually results in these factors, hence we also come to have a detail list of environmental factors which may influence RE process in GSD paradigm. Besides this, the initial list of environmental factors can also be one of the valuable input to the comprehensive list of complete factors which can influence the RE process in GSD.

B. *Future Work:*

The initial list of environmental factors is identified from the literature; therefore it lacks the input from the industry, so a more comprehensive list can be generated if both literature and industry are covered. These are the factors related to environment, a more comprehensive list can be generated by exploring the other areas also, which can influence the RE process in GSD paradigm.

The list only covers the global paradigm in future this list can be enhanced by including the factors from collocated development paradigm.

C. *Limitation:*

This study lacks the identification of factors from industry as the study comprises of the environmental factors which are identified from the state-of-the knowledge. We make every effort to cover all the related papers discussing environmental factors directly or indirectly for RE phase in GSD, but still it is possible that we may miss any published work. Similarly the paper is forwarded to other researchers in order to deal with biasness about the search protocol used, but still biasness aspect cannot be ignored as well. The threat of misinterpretation can also not be ignored, as it is one of the must factor in every literature review, although we tried our best to overcome these aspect by dealing it carefully. We also cannot ignore the threat related to precision. In our work we tried to have high precision rate but still the maximum precision is not assured.

VI. conclusion

Environmental factors are considered to be very influential while performing RE process in GSD paradigm. Our focus in this study was towards environmental aspects of RE in GSD paradigm where the teams are geographically distributed from each other. In specific we wanted to explore the environmental factors which may impact the software RE process in GSD paradigm.

We have used the systematic literature review method to identify the environmental factors and in order to have unique factors we used the constant comparison and memoing techniques of grounded theory. Total 38 papers are selected after applying the exclusion and inclusion criteria and identified factors and sub factors from them. The identified initial list of environmental factors can act as a reference list as well as the guidance for the practitioners and researchers who are working in RE field. However the initial list is only from the literature hence the industry is ignored for this study.

It will be very worth full if the industry is also involved for this initial list to make it even more comprehensive. Similarly every effort is made for the covering the maximum related papers, discussing environmental factors directly or indirectly for RE phase in GSD, but still it is possible that we may miss any published work. Similarly the paper is forwarded to other researchers in order to deal with biasness about the search protocol used, but still biasness aspect can not be ignored as well. The threat of misinterpretation can also not be ignored, as it is one of the must factor in every literature review, although we tried our best to overcome these aspect by dealing it carefully. We also cannot ignore the threat related to precision. In our work we tried to have high precision rate but still the maximum precision is not assured.

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