Analysis of the Effectiveness of Global Virtual Teams in Software Engineering Projects

H. Keith Edwards
University of Western Ontario, London, Ontario, Canada
hkedward@uwo.ca

Varadharajan Sridhar
Indian Institute of Management, Lucknow, India.
sridhar@iiml.ac.in

Abstract

Global software development projects use virtual teams, which are primarily linked through computer and telecommunications technologies across national boundaries. Global Virtual Teams rarely meet in a face-to-face context and thus face challenging problems not associated with traditional co-located teams. To understand the complex issues in a virtual project environment during the requirements definition phase of the software development cycle, we conducted an exploratory research study, involving 24 virtual teams based in Canada and India, working on defining business requirements for software projects, over a period of 5 weeks. The study indicates that ease of use of technology, trust between the teams and well-defined task structure influence positively the efficiency, effectiveness, and satisfaction level of global virtual teams.

1. Introduction

Software globalization has resulted in (1) software development activities spreading to emerging and developing nations and (2) software development moving away from the traditional co-located form to a form in which global virtual teams collaborate across national borders [2]. Large telecommunications and software companies have numerous software development groups residing in different countries around the world. The different groups work in a virtual setting, with members of the software development teams, interacting and communicating their work.

Apart from the low-cost advantage of developing software in India and China, organisations use geographically distributed software development groups in "follow the sun approach" to enable almost 24-hour software development cycle [2]. Leveraging global resources for software development has almost become a norm in companies such as Motorola, which has over 25-software development centres around the world [8]. Organisations also outsource their software development activities to contractors outside their home countries [10]. For example, India has a dominant offshore software development industry, which accounts for more than $6.4 billion in software export. This industry has more than 900 software export firms and employs approximately 415,000 software professionals [7].

These global software development projects use Global Virtual Teams (GVTs), which are primarily linked through computer and telecommunications technologies across national boundaries. GVTs rarely meet in a face-to-face context and thus face numerous problems not associated with traditional teams. Dube and Pare [5] outline several of the problems and challenges faced by GVTs. To equip and to train the students of software engineering to the challenges of working in GVTs, faculty in many schools have set-up Distributed Software Engineering Laboratories and conduct virtual team exercises in their courses. These exercises help students better understand the distributed collaborative software development process [8]. In this research work we present the findings from conducting such a global virtual team project exercise between student teams from the University of Western Ontario, Canada and the Indian Institute of Management, Lucknow, India.

2. Software Requirements Engineering and Global Virtual Teams

A software engineering project involves a number of different activities such as requirements specifications, analysis, design, coding, testing and implementation. The requirements definition phase of the software development life cycle is often cited as the most critical of the phases [14]. This is due to the fact that mistakes made during the requirements analysis phase cascade into the latter phases of the software development life cycle including functional specifications, code development, and implementation. Previous research has shown that mistakes made during the requirements phase can cost as much as hundred times as much as a coding error [15]. Thus, it is critical to have an exceedingly well-defined requirements document in order to ensure a successful project that meets the three metrics of on time, within budget, and in conformance to requirements.

Modern approaches to the requirement definition stage emphasize cross-functional teams, group collaboration and consensus decision-making techniques [9]. In the requirements definition phase of the software development life cycle, co-located teams comprising of users, business analysts and system analysts work closely to define the requirements definition artifacts. Gorton and Motwani [9] argue that if virtual teams are used in the requirements definition stage, the teams can exploit overnight gain effect due to the time difference between the locations where the teams are deployed which will reduce the cycle-time. It is also reported that apart from overnight gain effect, the teams can leverage on the expertise of the different GVTs, in developing robust requirements artifacts. They [9] further argue that for projects that are intended to be used in a global scale, cross functional teams from different parts of the world can capture the international requirements more aptly at the very beginning of the software development life cycle.

It is also to be noted that most of the offshore development centres such as those located in India and other developing countries are involved in coding, testing and bug fixing phases of the software development life cycle because of low-cost advantage. These are inherently low-value adding activities. Heeks, et al [10] argue that clients and software developers need to move their global outsourcing relationships up the value chain to reap greater benefits. One way for companies involved in software outsourcing business to move up the value chain is to undertake turnkey projects starting at the requirements definition stage until implementation. In this context, it is important to study whether the early stages of the software development process can be carried out at off-shore centres using virtual tea

In this exploratory study, we conducted global virtual team projects to develop software requirements definitions of business information systems. Our objective was to analyze the factors that significantly affect the quality of the requirements definition artifacts prepared by the virtual teams and to examine the effectiveness of the global virtual teams in performing these projects.

The rest of this paper is organized as follows: in section 3, we define the framework for analyzing the quality of virtual team projects and effectiveness of global virtual teams. Section 4 discusses details of the global virtual team projects conducted between students of IIML and UWO. In section 5, we present the data collected during this exercise and the analysis of the data. Section 6 lists the limitations of this study and the future research directions.

3. Framework for analyzing Global Virtual Team projects

In order to analyse the performance of Global Virtual Teams, it is necessary to develop a theoretical framework for analysing the team performance. Global Virtual Teams are dispersed across organizational, space or time boundaries and are often cross-functional in nature [9]. The development teams working in a global context has some advantages such as the ten and a half hour time difference between U.S./Canada and India, which can facilitate a near continuous software development cycle. However, it also has its share of disadvantages such as overcoming language and cultural barriers, co-ordination problems, and technology infrastructure problems [12]. It is important for organisations to find out the effectiveness of their global software development effort and the variables, which affect the effectiveness of these projects. In this section, we develop a model based upon current research models for virtual team performance.

Lurey and Raisinghani [13] present an empirical study, which examines the connections between the teams' tools and technologies and communication patterns and the teams' effectiveness in completing virtual team projects. In the meta-view model defined by them, the virtual team meeting outcomes (efficiency, effectiveness and satisfaction) depend upon the interaction within the meeting process of the group, task, context and technology factors that differ from situation to situation. We propose an extension of the model proposed in [13], that incorporates seven predictor variables and four outcome variables, and is shown in Figure 1. The quality of the requirements definition artifacts prepared by the virtual teams is measured by the marks (MARKS) awarded to the projects. We determine the effectiveness of virtual team exercise (LRNEFF) by how the team members felt about the learning process in virtual teams as compared to real co-located teams. Lurey and Raisinghani [13] point out that teams will not be effective if the team members themselves are not satisfied with the way team functions in a virtual setting. The project experience (PROJEX) is a measure of how satisfied/dissatisfied the team members are with the virtual team exercise.

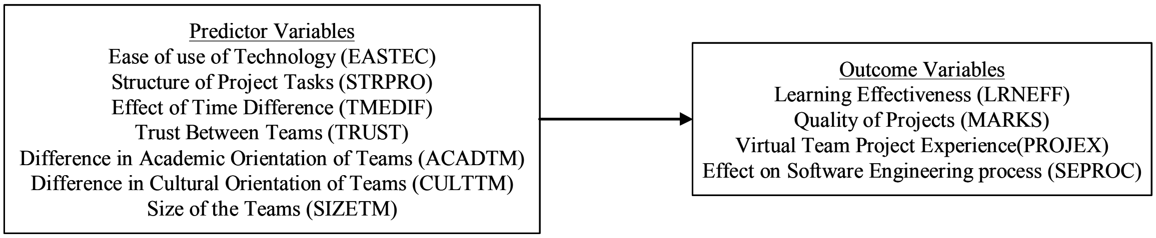

Figure 1. Model for assessing the performance of Global Virtual Team Projects

The fourth variable SEPROC, measures the impact of virtual team exercise on the software engineering process. This can be used to determine whether the virtual team exercise has brought any efficiency gain/loss in the requirements definition stage of the software development process. It is reasonable to expect that the learning effectiveness may be correlated positively with project experience and that the software engineering process improvement correlated positively with the quality of the projects.

In conjunction with the four outcome variables identified in the model, seven factors have been listed as predictors of the effectiveness of virtual team projects. The criticality of co-ordination and communication for the performance of virtual teams is mentioned in [3]. To overcome distance related problems, the students were encouraged to use both synchronous communication technologies such as chat and document sharing and asynchronous technology such as email. However the Internet bandwidth availability and the reliability of Internet services are different in the two countries. We measure the impact of communication technologies on the project by the variable EASTEC. The importance of “coherence” in task allocation where the work is split up according to feature content is cited as a critical activity for better performance of global teams [6]. The coherence of the task allocation and structure of the tasks in our projects were measured using the variable STRPRO. The positive effects of time difference on software project management to introduce “software shift work” have been well documented [9]. We analyse the effect of time difference between India and Canada in doing the project using the variable TMEDIF.

While it is difficult to hypothesize on the relationship between the predictor and outcome variables due to lack of previous research in this area, some general observations can be made based on the discussion above. EASTEC and STRPRO can be expected to have positive correlations with MARKS and SEPROC, while the correlation of TMEDIF with any of the outcome variables is ambiguous.

Trust has been cited as a single most important factor especially in the context where the parties involved in a business partnership do not see each other. There is wealth of research, which systematically examines the effect of trust in the context of electronic commerce [4]. However, the existing literature lacks to analyse the effect of trust on the effectiveness of global virtual teams. Hence we have included trust as one of the predictor variables that measures the extent to which the peer teams trusted their capabilities at the beginning and during the course of the project. It is expected that as trust improves, all the outcome variables can be expected to improve as well.

Carmel [2] extends the seminal work of Hofstede [11] on dimensions of national culture to the software development domain. The cultural differences include work ethic, work hours, preferred method of communication, revering hierarchy, individualism versus collectivism and concern for quality. The effect of cultural differences in student virtual team projects carried out between teams in Mexico and the U.S. is also cited by Favela and Pena-Mora [8]. We measured how the peer teams found culture to affect their virtual team project exercise using the variable CULTTM. Though culture may not affect significantly the quality of the project, it may have positive or negative influence on the virtual team project experience of the team members.

Capturing the software requirements involves a functional team, which knows the business requirements of the organization, and the technical team, which translates the requirements in to technical specifications. One of the objectives of this exercise is to explore whether the business domain expertise of the management students at IIML can be supplemented with the technical expertise of the computer science students at UWO in preparing requirements definition artifacts. Although it would be ideal to have technical expertise from India and business expertise from Canada to support existing real world software outsourcing models, the project constraints prohibited such a structure. ACADTM measures the effect of differences in academic orientation on the virtual team exercises. Based on the arguments above, we can expect ACADTM to have positive correlations with PROJEX and MARKS. Lastly the effect of size of the groups on doing the project was measured using SIZETM. Larger teams require more co-ordination and control, while smaller teams may find it difficult to complete the project activities before the deadline. Hence the correlation between SIZETM and MARKS or SEPROC is ambiguous.

4. Project Particulars

4.1. Differences between Teams

In order to do this, we arranged for 24 distinct teams from the Indian Institute of Management at Lucknow (IIML) and from the University of Western Ontario (UWO) to work together in a collaborative virtual team environment. Each team consisting of 5-6 members from IIML was paired with a counterpart at UWO consisting of about 3-4 members. In the early phases of the project definition, we felt that having teams from highly divergent backgrounds would provide for a large number of variables to study in the context of their function as a virtual team. In particular, there were several notable differences between these two teams:

- Educational Focus – The teams from the IIML were pursuing studies, which will culminate in a Master's degree in business administration whilst the students at UWO were pursuing a four-year undergraduate degree in computer science with a specialization in software engineering. Herein, we find two major distinctions. First, the students at IIML were graduate students and were thought to possess a larger degree of business experience than their counterparts at UWO. Second, the distinction between studies in computer science and business administration lent a degree of diversity to the teams that mirrored the business world.
- Country and Cultural Differences – One of the reasons behind having teams from two very different countries was to explore the impact of country and cultural differences on the interaction between the virtual teams. In particular, the interaction between India and Canada allowed us to explore the impact of cultural factors such as business environment, work ethic, preference for a method of communication, legal requirements, and leadership whilst maintaining a common language of English.
- Geographical Differences – Another reason behind the choice of such diverse groups was to explore the impact of geographical differences on the interactions between the two teams. In particular, India and Canada are located in opposite hemispheres of the world and feature a 10 hour and 30 minute difference between them. Thus, it was exceedingly unlikely that any of the teams would be able to co-locate.

4.2. Project Purpose and Deliverables

The purpose of the project was to have the students work together with their virtual team counterparts to develop requirements for a business information system. The project description specified that students were to choose a business information system that fulfilled a real business or organizational need. This was significantly different from previous course experiences where the computer science students had modelled trivial systems such as university enrolment or a library system. This project allowed students the opportunity to work with a system that closely mirrored the one in a real business environment.

The project also featured distinct roles between the groups that further reflected a real business environment. The students at IIML would assume responsibility for the conception of the business motivation behind the project whilst the UWO students would apply their skills in requirements analysis to define the system from a computer science perspective using Unified Modelling Language (UML). The deliverable for this specific project was a professional requirements document that reflected the expertise and the collaboration between the two groups.

In particular, the requirements document had several components based on requirements documents used in an industrial context [14]. In particular, this document featured several distinct sections including, but not limited to:

- Business use cases using UML to describe how the users were expected to use the system after its implementation.
- Business level class diagrams using UML. Business class diagrams are object-oriented classes with a selected set of attributes and the relationships between them. Typically, analysts do not specify operations and parameters for the classes until the design phase.
- A data dictionary describing the important data that the uses will require in the application.
- A high level description of the user interface using either a prose format or screen mock-ups.

- Portability, security, and reliability needs for the application based upon its proposed industrial utilization.
- Estimates of performance metrics such as estimates for response time, throughput and disk space utilization.

In addition to the requirements document deliverable, the project had several learning objectives relating to the virtual teams experience that were distinct from the requirements document. Both instructors communicated these learning objectives to the students through lectures and handouts.

- To participate in a collaborative virtual team project with the students from another university and culture in defining the requirements of a business information system
- To experience the sprit of global software development and appreciate temporal, cultural and other differences that exist in such an environment
- To experiment with synchronous and asynchronous collaborative technologies
- To document and analyse the experience of the virtual team project

4.3. Project Timeline

While first conceptualised and planned during the fall of 2001, the actual course project took place over a period of five weeks beginning on January 7, 2002 at the start of classes at UWO. On January 9, 2002, we divided the students at UWO into 24 distinct teams. The teams at IIML had already been established from previous projects in the MBA program. The next week (January 14, 2002), we paired the IIML and the UWO groups and provided the electronic mail addresses for members of both groups. To facilitate this communication, each university hosted websites that featured the electronic mail addresses and photographs of each team. The students then had the remainder of the week to meet with their counterparts and to decide on a project topic which was submitted in a paper format and also posted to each group's website.

From January 18, 2002 until February 6, 2002, the students worked together in their virtual teams to further define the requirements of the system under consideration. At the end of the day on February 4th, we required that each group post the majority of their requirements document to the web. This information included the information discussed in the description of the requirements document above, but did not include the project report and several of the other minor portions of the requirements document such as a listing of the available documents and the open issues faced by each team. On February 6, 2002 the students completed their requirements documents, and each team turned in the complete document to their course instructor. Table 1 highlights the project milestones and deliverables for this project. All 24 of the student groups completed their projects on time and submitted the requirements document and project report. These documents ranged in size from 24 pages to 107 pages. As a result, the projects required about 2 weeks to evaluate. During this time, the instructors for both courses communicated regarding the quality of the documents and grades for the projects.

Table 1. Project Milestones and Deliverables

Project Milestone / Deliverable	Due Date
Formation of groups at IIML/UWO. At IIML, 25 groups should be formed with not more than 5 in a group	Wednesday, Jan 9, 2002
Pairing of IIML and UWO groups. Exchange of email addresses of paired groups	Monday, Jan 14, 2002
Project Topic and a brief description of 250 word abstract of the project mutually accepted by the groups, posted on the designated course web site	Friday, Jan 18, 2002
User population, Use Cases, Important Data/Data Dictionary, Functional Requirements, User Interface, Security/Privacy Requirements, Portability requirements, Reliability Needs, Response Time and Disk Space mutually accepted by the groups, posted on the designated course web site	Monday, February 4, 2002
Project Report containing the requirements document and an analysis of technologies used, and relevant experiences	Wednesday, February 6, 2002

There was a strong positive correlation between the grades received by each group, indicated by the Pearson correlation coefficient of 0.92, significant at 0.01 level. This indicates that the peer teams did comparable work. After the completion of the requirements document, the UWO group was required to complete two more phases of the project. These two phases were the creation of a functional specification and a prototype of their system for customer review. While the teams were no longer required to stay in direct contact, several of them did through the functional specification. At least three groups at UWO obtained a customer sign-off for the functional specification

5. Survey Data Collection and Analysis

A systematic and rigorous approach is required to develop measuring instruments. Measurement items, which fit in to the constructs defined in the model shown in Figure 1, were generated using the cited literature. In this study, 61 items were generated based on survey responses from the 116 IIML students and 85 UWO students, who participated in the global virtual team exercise. All items were measured on a seven-point Likert-type scale, where 1/7 would mean that the respondent strongly disagrees/agrees to the construct item. Demographic and experience items were measured through direct questions. The large sample size minimizes the subjective bias in the outcome variables. Factor analysis was performed on the pooled sample to assess construct validity. The items, which did not load well on the constructs, have been removed. Finally 38 items were selected and the reliability of the constructs was further validated by computing reliability coefficients for each construct. The reliability statistics are given in Table 2, along with the number of items indicated next to each construct. All the constructs have a Cronbach's alpha closer to or greater than 0.70 and hence prove construct validity [4]. The constructs STRPRO and SIZETM had only one item in each and hence are not shown in Table 2.

The mean scores of the predictor and outcome variables for the two teams are presented in Table 3. From the table, we can draw several conclusions. In particular, the teams did not have much difficulty with the communication technology they used. The UWO team found the activities and milestones of the project to be less structured. This is surprising since the mean age and work experience that are indicative of maturity were higher for UWO team members than that of IIML team members. One possible explanation could be that the management curriculum at IIML, as is typical of the MBA programs, encourages work in an unstructured environment compared to the undergraduate computer science curriculum at UWO. This might have enabled IIML students to better cope with gaps in the structure of the project exercise.

Table 2. Reliability Statistics of the Constructs

Constructs	Reliability Coefficient
Learning effectiveness (3)	0.8308
Virtual team project experience (10)	0.8415
Effect on software engineering process (7)	0.7068
Ease of use of technology (2)	0.7193
Effect of time difference (4)	0.6760
Trust between teams (4)	0.6971
Difference in academic orientation of teams (3)	0.7613
Difference in cultural orientation of teams (3)	0.8332

Table 3. Mean Scores of the Predictor and Outcome Variables

Variables	Mean Scores	
	IIML	*UWO*
Predictor Variables:		
Ease of use of technology	4.2500	4.2143
Structure of the project tasks	4.6261	3.5529
Effect of time difference	4.6875	4.8029
Trust between teams	5.2371	4.8000
Difference in academic orientation of teams	3.7813	4.4156
Difference in cultural orientation of teams	2.6339	3.2946
Size of the teams	3.7632	3.9059
Outcome Variables:		
Learning effectiveness	5.7531	4.6194
Virtual team project experience	5.5000	4.2746
Effect on software engineering process	4.8617	4.1504

Both the teams felt that the difficulties and challenges due to time difference was more than average. It has been observed that in global software teams, trust level is lower at the start of the project leading to reluctance to share information. This may be because of insecurity and the teams did not look themselves as partners working towards a common goal. Over the course of the project, trust develops between the teams. In our project, even though the project duration was very short, both the teams trusted each other to the same degree with the trust level found to be high. Prevalence of high amount of trust indicates that given a suitable environment, very similar to a university environment where creativity is encouraged and there is no power hierarchy, it is possible to build good trust between the virtual teams.

Differences due to academic orientation of the teams (business versus computer science) and cultural (Indian versus Canadian) were perceived by the teams not to have significant impact on the exercise. This is similar to experience of the global software team of Motorola as given in [1]. Both the teams were indifferent about the team size.

IIML teams felt that their learning process was strengthened by the virtual team exercise while the UWO teams were more moderate in their response. The same holds true for the overall experience about the virtual team exercise. The grades for the virtual team exercise were equal for both IIML and UWO teams. However, since IIML team did not take part in the subsequent phases of the project, their stakes were limited. Due to commitment to the subsequent phases of the project, the UWO teams might have perceived more risk and found the project to be more complex. Hence, they may have rated the effectiveness of the virtual team exercise lower.

From the above we can conclude that UWO team was moderately poised whereas IIML team more positively poised in their view towards the virtual team exercise. One reason may be that if the risks, deliverables and the time of involvement are less, then global virtual team exercise will be more favored.

In addition to the above descriptive statistics, Pearson's product-moment correlations between the predictor variables and outcome variables were performed which revealed significant results. Table 4 shows the correlation coefficients for the predictor and outcome variables.

The difference in time, culture and size of the teams, did not have any significant correlation with any of the outcome measures. Furthermore, the quality of the projects as measured by the marks awarded to the virtual team project did not have any significant correlation with any of the predictor variables.

From the results in this table, we see two significant results for the performance of virtual teams. First, as technology becomes easy to use and the structure of the project increased, the effectiveness and satisfaction level of the team members as well as the efficiency of the software engineering process increased. Thus, organizations undertaking virtual team projects should provide a sound structure to the project and seek to ensure that teams feel comfortable using the technology inherent with virtual teams.

Trust between the peer teams has significant positive association with the virtual team project experience of the students as well as the learning effectiveness of the team members. An increase in trust also increases the efficiency of the software engineering process itself. The difference in academic orientation between the peer teams in fact, has a negative association with the project experience of the team members and the efficiency of the software engineering process. This however, is opposite to our expectation. The hypothesis that heterogeneous teams actually can contribute positively in a global virtual team setting needs further examination. All the other correlations were of expected sign as discussed before, but the associations were not strong.

Table 4. Correlation between Predictor and Outcome Variables

Predictor Variable	LRNEFF	MARKS	PROJEX	SEPROC
EASTEC	0.156*	0.049	0.246**	0.213**
STRPRO	0.277**	0.077	0.432**	0.429**
TMEDIF	0.079	-0.014	0.010	0.101
TRUST	0.398**	0.172*	0.546**	0.551**
ACADTM	-0.098	-0.004	-0.218**	-0.191**
CULTTM	-0.107	-0.138	-0.134	-0.067
SIZETM	0.007	-0.017	0.022	-0.014

(All Pearson correlations reported are for two-tailed tests. *correlation significant at the 0.05 level and ** correlation significant at the 0.01 level)

Table 5 shows the correlation amongst the four outcome variables. The correlation matrix indicates that there are significant positive associations between learning effectiveness, virtual project experience and the software engineering process outcome as expected. However, the positive correlation between the efficiency of the software engineering process (SEPROC) and the quality of the projects (MARKS) was not significant.

The students were also asked to specify how many hours they spent on this virtual team exercise during the five weeks of project duration. Correlations significant at 0.01 level were observed between hours spent and the outcome variables: MARKS (coefficient=0.199), LRNEFF (coefficient=0.315), and PROJEX (coefficient=0.253).

Table 5. Correlation between the Outcome Variables

	MARKS	LRNEFF	PROJEX	SEPROC
MARKS	1.000	0.004	0.042	0.069
LRNEFF		1.000	0.783**	0.711**
PROJEX			1.000	0.773**
SEPROC				1.000

(All Pearson correlations reported are for two-tailed tests. *correlation significant at the 0.05 level and **correlation significant at the 0.01 level)

6. Conclusions and Future Research

The use of virtual teams in the construction of industrial software is becoming more and more commonplace as corporations seek to take advantage of lower costs and to utilize a follow-the-sun approach to software development. In this paper, we sought to examine the factors that impact the quality and performance of global virtual teams engaged in the requirements definition phase of the software development life cycle. Even though this study was limited to the requirements definition phase of the project, the phase is very critical for the quality of the software product and requires effective communication between the business process teams and systems analysis team. Realities of global software development environment were closely simulated using heterogeneous teams spread across the globe.

The study yields several interesting conclusions that can assist organizations in creating and managing their global virtual team projects more effectively. The study indicates that ease of use of technology, trust between the teams and well-defined task structure influence positively the efficiency, effectiveness, and satisfaction level of global virtual teams. These parameters can be used by organizations to improve the outcome of global virtual team projects.

As part of the software engineering and information systems curriculum, the global virtual team projects were perceived positively by the students. There are significant positive associations between learning effectiveness, virtual project experience and the software engineering process outcome. The project exercises give students exposure to the realities of global software development environment.

While this exploratory study makes some initial observations into the nature of global virtual teams during the requirements definition phase of software engineering projects, there exist several potential directions for subsequent research. First, a subsequent experiment can be conducted that examines the outcomes of such an experiment where the software development team is located in India, which is often the case due to low software development cost, and where the management functions are located in Canada. A project management team can be deployed to co-ordinate the activities of the teams at the two sites. This would more closely mirror the process used in real world development environments.

Organizations are trying to move their outsourcing relationship up the value chain and including all phases of system development, they incur costs and risks as indicated by Heeks, et al [10]. An interesting extension of this exercise would be to conduct projects in which the different phases of the system development life cycle are distributed amongst multiple non co-located virtual teams. Quantifiable metrics should be developed to assess the performance of the teams across the different phases. This can help in devising ways by which companies can minimize risks and reap maximum benefits by selectively outsourcing the phases of software development projects. The project also can illustrate how domain expertise can be tapped across the globe by integrating the management and process knowledge with software expertise available at distant locations as discussed by Battin, et al [1].

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