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GLOBAL VIRTUAL ENGINEERING TEAM UTILIZATION IN THE ENGINEERING, PROCUREMENT, AND CONSTRUCTION (EPC) INDUSTRY

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by

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ABSTRACT

Advancements in communication and information technology make it possible for global virtual engineering team (GVET) members to work as a team whether they are collocated or geographically distributed. A Global Virtual Engineering Team (GVET) is a group of geographically dispersed individuals organized through communication and information technologies that need to overcome space, time, functional, organizational, national, and cultural barriers for the completion of a specific engineering task. Global companies in the Engineering, Procurement, and Construction (EPC) Industry face many challenges, both managerially and technologically, when using GVETs.

The primary goal of this research is to investigate the use of global virtual engineering teams within a multi-office execution strategy for the execution of capital projects in the Engineering, Procurement, and Construction (EPC) Industry. This thesis aims to increase the understanding of effective global virtual engineering team utilization through identifying and ranking the driving factors for using distributed teams, challenges, origin, current status, future trends, and success / failure factors.

A literature review aided in the definition of a global virtual engineering team along with identifying GVET features and different perspectives. A survey of the industry was then performed. 46 industry members responded to an online questionnaire. The majority indicated the need to reduce engineering service cost as the primary driving factor in adopting a multi-office engineering strategy. Interviews with 21 domestic and international executives, and a detailed case study outlined major challenges, experiences, and success factors for implementing project with a GVET. Clear and frequent communication; periodic face-to-face meetings; good communication tools; and IT compatibility were identified as the most critical success factors during GVET implementation. Detailed results from the survey, interviews, and case study are presented along with a discussion of future research needs.

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CHAPTER 1

INTRODUCTION

The increase in globalization and recent technological developments have taken businesses on a new trajectory, that has changed where and how companies do business. Many of these changes have been driven by the transforming and continuing impact of the dramatic progress in information technologies. The concept of virtual teaming has been around for over 20 years. But it was only within the past 10 years that larger scale multi-office execution strategies for performing engineering services began in the EPC Industry. The business model for many EPC companies in five years will have global execution at its core (McQuary 2003). Global execution will require global collaboration from locations with limited fixed IT infrastructure. Some of the challenges facing EPC contractors, according to McQuary (2003) are: attracting, retaining and educating the work force; more revamps and modernization projects at existing locations; and more multiparty EPC execution.

No longer is it only manufacturing, data processing and call center jobs that are being moved overseas. A growing number of firms are now also moving engineering design and development work to overseas countries. In today's global business environment, the engineering costs are of paramount interest to both owners and contractors. Most importantly, the facility owners want a lower cost, but want the EPC contractor to assume more risk and meet a tighter schedule. Companies have begun to consider various strategies to reduce the cost of their capital projects. As mentioned by one of the EPC company from the case study project within this research, one such strategy is through globally competitive sourcing of engineering services. Companies are also keen complete new facilities faster so they can release the end product to the market as early as possible. Therefore, profit earning can be realized much earlier. This leads to companies focusing more on schedule driven projects. The around the clock work schedule for engineering work with the use of

Global Virtual Engineering Teams (GVETs) is recognized as adding value to schedule driven projects. Also, another scenario where GVET utilization can be favorable is considering the project location. Companies within the EPC Industry may try to locate services close to the project location or equipment / vendor locations.

An effective implementation of a global engineering strategy through GVETs requires a deeper understanding and identification of the various critical factors that may not be found or be as important in traditional business practices. Global virtual engineering teams have many cultural, economic, political, and technological aspects that must be evaluated and addressed in order for their successful execution. But before the implementation stage of a project, the most vital question that requires an answer is whether a company should adopt such a strategy or not. Some of the many important questions related to the successful performance of global engineering teams include:

- What are the best practices for establishing and maintaining global engineering teams?
- What are the minimum and optimum technical and managerial requirements for a virtual engineering team system?
- What are the most critical success factors in implementing virtual engineering teams?

Companies are still pushing forward to implement effective distributed teams by overcoming the mentioned challenges. This research aims to better understand the rationale behind the adoption of this strategy by identifying the drivers for the utilization of global virtual engineering teams. To better understand the driving factors, it is important to understand the evolution of the global engineering concept. Perspectives of multi-office execution strategies and as well as other applications of GVET strategies need to be carefully reviewed. The origin, current status, and future trends are assessed in this research. The documentation of the results from this research will aid companies during their business planning or pre-project planning stage to decide whether to develop a global virtual engineering team for their future businesses or to make use of such teams for their current projects. The results can also help create awareness within academia regarding the impacts of globalization.

1.1. Introduction to the Research Problem

Changes in technology, the marketplace, information systems, the global economy, social values, work force demographics, and the political environment all have a significant effect on the processes, products and services produced by an engineering team. The culmination of these forces has resulted in an external environment that is dynamic, unpredictable, demanding and often devastating to those organizations which are unprepared or unable to respond (Church et al. 1996).

With resources dispersed in various geographic locations, global companies have been facing many challenges related to the integration of these services, both managerially and technologically. With improvements in modern communication technology, it is now possible to adopt virtual teaming strategies that facilitate better communication and management of global design teams.

Further investigation is needed to analyze the use of virtual teams for global engineering design projects. The driving factors are identified and analyzed to verify whether it is in a company's best interest to adopt such a strategy. To remain competitive and to succeed in the application of a GVET or multi-office execution strategy for engineering design services, companies are working towards identifying and troubleshooting these challenging issues as early as possible. But lacking documented past experience, analysis tools or some form of formal guidance to predict the schedule and resource requirements for their projects, companies or individual managers within a company can overlook important issues. A decision made in an intuitive manner does not always guarantee success. Team members generally scatter at the end of a project, so that any tacit knowledge about how to organize and implement the GVET execution better the next time disperses with them.

But before overcoming most of the above issues, a preliminary phase of research in documenting the driving factors, current status of global virtual engineering teaming, future trends, tools used, successful work processes, lessons learned, and other critical items is necessary. This research focuses on documenting these preliminary aspects. The research was conducted as part of a larger project performed by the Construction Industry Institute (CII) with Project Team 211. The Construction Industry Institute (CII) is a research institute for engineering and construction that is comprised of more than 90 member organizations, representing leading owners, contractors, and suppliers in both the public and private sectors. The members fund studies at universities to identify ways to improve the planning and execution of major construction projects. The project team, herein after referred to as 'CII PT211', includes members from industry and academia (see Appendix G for team members list).

1.2. Goal

The primary goal of this research is to investigate the use of global virtual engineering teams within a multi-office execution strategy for the execution of capital projects in the Engineering, Procurement, and Construction (EPC) Industry.

1.3. Objectives

The following five main objectives of this study were identified:

1. *To determine the driving forces for global virtual engineering teams.*
   Earlier research on this subject addressed a few drivers for implementing global virtual engineering teams, but no public study has quantified or identified these drivers with respect to the EPC Industry's rating. Therefore, to comprehend the concept and impact of GVET, it was vital to identify and rank the driving forces

in the order of importance by the EPC Industry. The development of a survey served as the data collection instrument for achieving this objective.

2. *To determine the current status of global virtual engineering teams, tools and work processes.*
   Understanding the status quo of the virtual team concept is a starting point from where the directions for improvement can be identified. This includes the current status of GVET at an EPC Industry level, types of collaborative tools used by companies or projects where virtual teams are applied, and aspects such as work processes. The online survey questionnaire, current literature, and industry interviews aided to accomplish this objective.

3. *To determine the trend with companies toward performing more or fewer projects with global virtual engineering teams.*
   This includes aspects such as acceptance of the concept at an EPC Industry level and the company's perspective on the GVET concept being adopted for future projects. This objective is important to realize the significance of this strategy in today's businesses in the global economy.

4. *Document the most important success/failure factors that lead to successful / unsuccessful utilization of global virtual engineering teams.*
   Targeted interviews with EPC Industry experts and a detailed case study helped to identify best practices and critical success / failure factors regarding how executives perform cost/benefit analysis when considering the decision to use a global engineering team for a project. The drivers for, and obstacles, to global engineering teams are also identified and how executives address them to come up with the conclusion whether or not to use a global design group for a project. Other virtual teaming issues will also be examined.

1.4. Definition

After a careful review of the definitions from current literature combined with input from CII PT211 members, the following definition for Global Virtual Engineering Team was adopted in this research:
A Global Virtual Engineering Team (GVET) is a group of geographically dispersed individuals organized through communication and information technologies that need to overcome space, time, functional, organizational, national, and cultural barriers for the completion of a specific engineering task.

1.5. Scope Definition and Limitations

This study is focused of GVETs for engineering services on capital project in the Engineering, Procurement, and Construction (EPC) Industry. The EPC Industry companies that are the focus of this research design and construct major capital projects, e.g., chemical plants, power plants, infrastructure, pharmaceutical plants, oil and gas platform, mining facilities, nuclear plants, and other large facilities. This research makes a distinction between an Owner and EPC Contractor. The Owner is the financial investor who invites EPC Contractors to bid on large capital projects and facilities worldwide. The EPC Contractor is responsible for providing services (e.g., designing, constructing, and managing of all project issues) and then the turning over the project to the Owner. The contractor is not just building a facility, but they may also train personnel to own and operate the facility and developing a work force to help build the facility.

This study is limited to primarily large Owners and EPC contractors that are CII member companies. The CII PT211 research was based on the subject ‘Effective Use of Global Virtual Engineering Work force’. This group had an even separation of members representing both Owners and EPC Organizations.

This research draws on driving factors and best practices of the EPC organization and also from an Owner organization's perspective. The incorporation of current status, future trends, virtual teaming concepts, analysis of management techniques to support the virtual teaming approach, critical skills, and the use of communication and information technologies as enabling tools to improve the efficiency and effectiveness of global design teams are emphasized.

This study does not include an implementation tool that incorporates recommended practices and associated examples for evaluating and formulating global virtual engineering team strategies on engineering projects and for engineering offices. The CII PT211 team is working on the development of such a tool as a follow-up to this preliminary research. The Go-No Go decision or a decision support tool to evaluate if the company should engage in the use of a global engineering work force is also not within the scope of this research.

1.6. Reader's Guide

This thesis includes six chapters. Chapter One presented an introduction to the research problem along with the goals, objectives, and scope limitations of this study. Chapter Two described the detailed research procedures that were used to meet the objectives of this research, including three primary research techniques that are used; Questionnaires, interviews, and case study analysis. Chapter Three provides a review of the existing literature for engineering services, the GVET definition, current trends, driving forces, and different perspectives on global outsourcing of engineering services.

Chapter Four illustrates the data collection, data analysis, and research results from this research work. All the significant results from the survey and interviews are outlined in this chapter. The case study project can be found in Chapter Five. The thesis report is concluded in Chapter Six with a research summary, research contributions, research limitations, and an outline of possible future research.

CHAPTER 2

RESEARCH METHODOLOGY

Qualitative and quantitative data offer distinct, but complementary insights into team dynamics, supporting the view that understanding virtual team processes requires multi-faceted research approaches (Steinfield et al. 2001). This chapter illustrates the research methodology used throughout this study. Various research techniques and the rationale for their use are outlined in this chapter.

2.1. Research Procedure

Several different research techniques were used in this study. These techniques comprise the questionnaire or survey method; case study research method; interview techniques; and content analysis. The following sections provide a description of each of these research techniques. This section describes the research processes that were performed to achieve the objectives of this study.

2.1.1. Literature Review

A literature review was performed on various topics ranging from the current status of global virtual engineering teams, drivers, critical factors, and offshore sourcing of engineering services. Review of the literature from academia and industry was carried out including the following aspects; globalization of the engineering design work force; virtual teaming in the EPC Industry; team structure; outsourcing from both critics and supporters; communication effectiveness; current collaboration tools; and business drivers. Members of the CII PT211 team were surveyed to identify unpublished internal materials focused on this topic. Some of the available statistical data regarding the global market along with past, present and future trends of outsourcing are summarized from various sources such as academic research papers, journal papers, Engineering News Record (ENR), U.S. Department of Labor-Bureau of Labor Statistics, and the Wall Street Journal. The literature review performed for this study is presented in Chapter 3.

2.1.2. Global Virtual Engineering Team Definition

Many definitions were obtained from the literature review. The definitions from these various sources contained similar elements. Some of the sources started by comparing virtual teams with conventional teams. But most definitions were not specific enough with regards to global and engineering aspects. Therefore a definition was developed that incorporated not only the features found in traditional teams, but also stressed the global and engineering facets. This definition development is included in Chapter 3.

2.1.3. Questionnaire or Online Survey Development

A questionnaire is a research instrument consisting of a series of questions that people answer about their life condition, beliefs, or attitudes (Thomas 2000). The main advantage of this method is its quantitative aspect. Questionnaires are less expensive than interviews, they are self administering, they can be administered to many persons simultaneously, they can be mailed, they are logistically easier to manage than interviews, and they call for uniform responses (although items may often be subject to widely different interpretations). At the same time, they are impersonal and limit the respondent's response range significantly (Guba and Lincoln 1981).

Surveys by questionnaire were performed. These surveys were sent to CII member companies. During the survey development phase, two different survey formats were developed; One for Owners / Operators and one for EPC Organizations. This survey questionnaire was prepared to obtain a significant amount of data with regards to the current status, tools, work processes, and drivers for using global virtual engineering teams by both owners and EPC organizations. A brainstorming session with the CII PT211 project team members was performed to identify appropriate questions for the questionnaire. The brainstorm list was refined into survey questions and then a draft of the questionnaire was sent to the CII PT211 team members for feedback. A conference call was organized for input from the team members. After further review, feedback, and processing of the collected information from the CII PT211 members, two questionnaires were developed and posted online. The website address to the survey was then sent to all the PT211 team members and all CII data liaisons (approximately 100 companies). Both versions of the questionnaire survey are included in Appendix A (Owner Organization Survey) and Appendix B (EPC Organization Survey). Figure 1 shows a snapshot of a portion of the online survey pages.

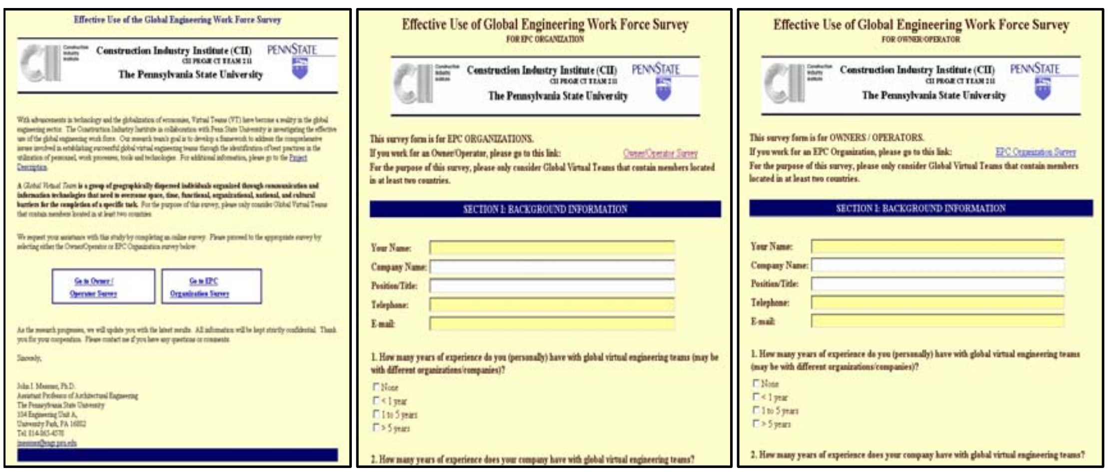


Figure 1: Online Survey Pages (partial)

An important factor that was considered while developing this survey was to keep open-ended questions to a minimum. This was done to get the maximum number of responses to the survey. A total of approximately 100 companies were identified for the survey process. Most companies were Construction Industry Institute (CII) members. The survey results are presented in Chapter 4. The comprehensive results of the survey can be found in Appendix C.

2.1.4. Preliminary Unstructured Interviews

To obtain qualitative results from this study, in-depth interviews with decision-makers (both domestic and international) and engineering team members were performed. This research aimed to incorporate two approaches towards interviewing. One was to perform structured interviews where the objective is usually to get representative or 'typical' responses, and 'a deviation is ordinarily handled statistically' (Dexter 1970). The other format would be to perform unstructured interviews which are typically used in any of the following circumstances (Guba and Lincoln 1981):

- When the interviewer is dealing with elite subjects, that is, subjects who have special status or knowledge;
- When the interviewer is interested in pursuing some subject in depth;
- When the interviewer is operating in a discovery, rather than a verification, mode;
- When the interviewer is interested in the etiology of some condition;
- When the interviewer is interested in a direct interaction with a certain respondent;
- When the interviewer is interested in uncovering some motivation, intent, or explanation as held by the respondent (Dexter 1970); or
- When the interviewer is trying to ascribe meaning to some event, situation, or circumstance.

When performing interviews, it is important to consider interviewer bias. Bias is "a tendency to observe the phenomenon in a manner that differs from the 'true' observation in some consistent fashion" (Simon and Burnstein 1985). One method to reduce the impact of bias is to perform an unstructured interview or to develop questions that do not require the interviewee to answer within the interviewer's framework. Another method is to systematically analyze the interview data by a content analysis procedure. Content analysis is a phase of information processing in which communication content is transformed, through objective and systematic application of categorization rules, into data that can be summarized and compared (Holsti 1969). In this study, the particular technique used during the content analysis was to carefully listen to the audio recordings of the interviews and then organize the relationships between concepts and domains discussed in that interview. A sample interview content analysis map from an initial interview is shown in Appendix F.

Most of the interviewees identified for the interview phase of this study were domestic executives and international executives in the EPC Industry. This preference was due to the fact that most of the executives were decision makers who were directly involved in whether or not to adopt the use of global engineering teams. Their experiences and lessons learned after its implementation would prove valuable for this research.

Unstructured telephone and personal interviews were performed with a portion of the survey respondents and also with contacts provided by several CII PT211 members. As per the reply to the online survey questionnaire, 70.5% of the EPC owners and 84% of the EPC contractors who responded to the original survey were willing to be interviewed for this study. A preliminary unstructured interview was performed with some of the domestic and international industry executives. Both face-to-face and telephone interviews were performed depending on the location of the interviewee and his or her availability. The participant’s permission to audio record was requested. The duration of the interviews ranged between 30 to 55 minutes. The interview questions were developed from some of the preliminary results of the survey, literature review, and also from the brainstorming session with the PT211 members. Some of the open-ended questions that weren’t incorporated in the questionnaire survey were included in the list developed for interview questions. The interview questions from the steps mentioned above are included in Appendix D.

To gain more insight into the global virtual engineering teaming concept, the interview questions were categorized into six sections: background information;

organizational level decision; project level decision; best practices for successful implementation; case study examples; and concluding questions.

The goal of collecting background information was to gain an understanding of the level of responsibility and experience of the interviewee with global virtual teams. The second section touched upon the corporate infrastructure aspect such as the startup costs for setting up an offshore office, company requirements to develop and improve the skills within their company for optimal performance in such a global virtual environment, etc. Another example could be which geographic location would prove to provide a strategic advantage for the company against other competitors. The third section is more project oriented. This focuses on the details of specific projects such as the work sharing / work breakdown structure of a particular project, technology requirements, intellectual property concerns, local culture, and motivation of individuals within that particular geographic location where the project is located.

The fourth section addresses the past experiences of the interviewee during successful implementation of the global virtual teaming strategy. Some of the best practices and critical factors with examples were collected. The fifth section was intended to obtain information on a real project example that was successful or unsuccessful during the company's adoption of this strategy. The last section aimed to obtain the interviewee's thoughts regarding the future trends of global virtual teaming and any other additional comments or items that they feel are important for this research.

2.1.5. Data Organization and Analysis of Results

The data received from the survey was summarized in a tabular form. Based on the number of responses to each question, the final results are represented as an average percentage or in another appropriate format. The results can be seen in Appendix C. Some of the results such as the driving forces and success / failure factors are organized based upon decreasing order of importance and frequencies respectively.

To meet the research objectives, the case study and the interviews were closely analyzed to obtain the necessary information such as lessons learned.

2.1.6. Case Study Research Method

A more detailed case study of a company and their implementation of GVET for projects was carried out. This research used a case study research method performed through in-depth interviews with several executives that have a significant amount of experience in managing projects with a global virtual engineering team. Case study research is very useful in research areas where (1) the research question addresses ‘how’ or ‘why’, (2) there is little control of the events, and (3) the focus of the study is on contemporary events (Yin 1989).

A detailed case study on the implementation of virtual engineering teams in the EPC Industry, both successful and unsuccessful, was investigated. A case study example for this research was identified from a CII member company. A sample set of case study questions were developed for the case study interviews. They are included in Appendix E. The case study revolved around 5 projects performed during different periods of time; from the early stages when the company just introduced the strategy until recent. This case study describes the events and evolution from the early nineties when the company first introduced global virtual engineering teaming on one of their projects. It explains some of the early experiences with technology, data transfer, management issues, work processes, key success factors, and examples of failures associated with the five projects. The complete case study developed for this research is included in Chapter 5.

2.2. Summary

This chapter explained the research methodologies that were used for this study. These methods were utilized to obtain both qualitative and quantitative information to better understand the GVET concept. The next chapter introduces existing literature that is related to this research.

CHAPTER 3

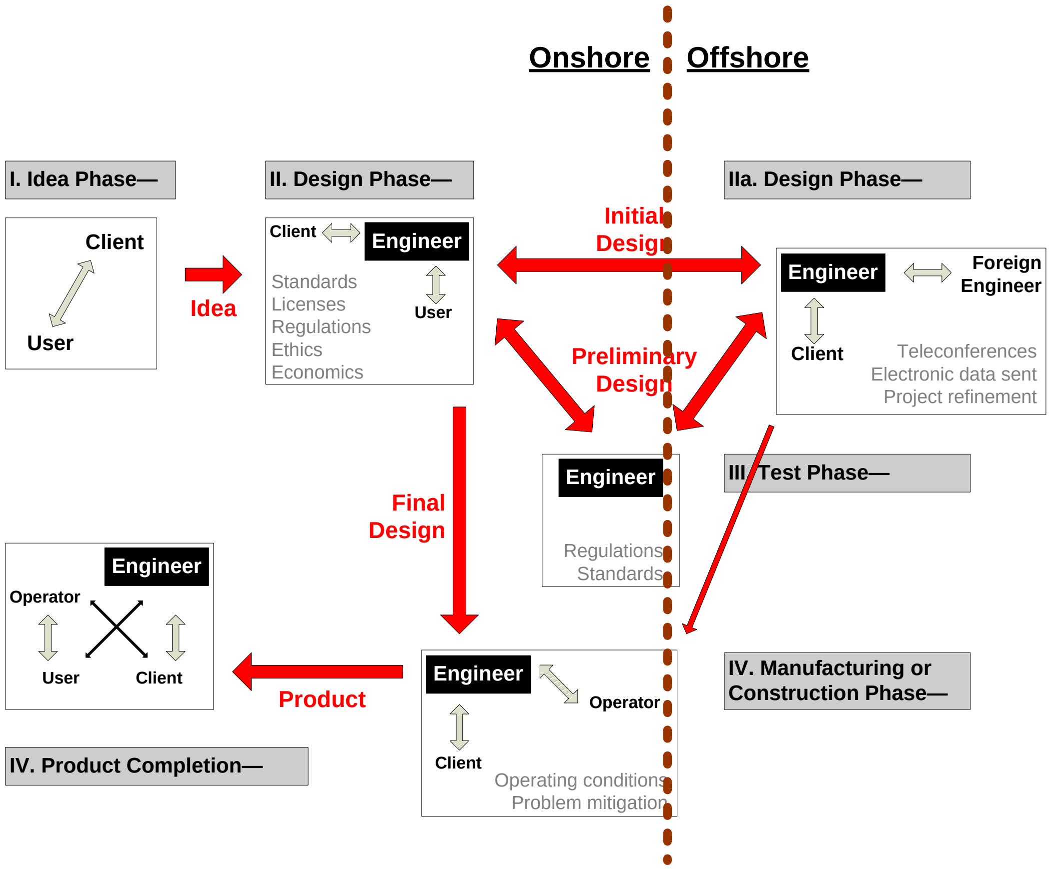
LITERATURE REVIEW

This chapter describes previous research related to various topics that influence the effective use of global engineering work force by organizations. Review of the literature from academia and industry was performed. The CII PT 170 research project on virtual teams (Chinowsky and Rojas 2002) examined the purpose and success factors for using virtual teams on projects. This research helped define some of the basic parameters and also some specific recommendations for virtual teams which will be described in the following sections. Another related research project is from the Center for Integrated Facility Engineering (CIFE), Stanford University that discusses modeling and monitoring trust in virtual AEC teams (Zolin et al. 2000). Trust development in virtual teams presents significant challenges because it is difficult to assess teammates' trustworthiness without ever having met them (McDonough et al. 2001).

Much literature related to GVETs is framed within the offshore outsourcing concept. Therefore, background literature on offshore outsourcing of engineering work including the driving forces, virtual team definition, wage difference, future trends, pros and cons is presented. Global virtual engineering team structures related to technology; management; organization; project control; and team communication are also described.

3.1. Engineering Services

A better perception of engineering teams requires an understanding of the definition of engineering. The International Technology Education Association (2004) defines engineering as involving "the knowledge of the mathematical and natural sciences (biological and physical) gained by study, experience, and practice that are applied with judgment and creativity to develop ways to utilize the materials and forces of nature for the benefit of mankind." Engineering work is seen as an iterative process of design and analysis. There are many stages—planning, design, manufacturing or construction, and then operation (see Figure 2).



I. Idea Phase—Identification of a problem or an idea: new building, product, improvement.

II. Design Phase—The engineer analyzes the idea or problem. Designs solution under guiding factors listed below.
IIa. Design Phase—The engineer conveys the scope of the work to be done to the foreign engineer. The foreign engineer either does design work or manufacturing work.

III. Test Phase—The engineer applies the design to a model to test— can be done domestically or abroad at the offshore site. This applies to manufactured products.

IV. Manufacturing or Construction Phase—The engineer supervises the manufacturing processes domestically or abroad (for elec. and mech. engineers). Construction (mainly for civil engrs.), or improvements made to a plant or operating system, all done domestically.
IV. Product Completion—Engineer or manufacturer may simply hand product over to the client (i.e. electrical device), may sell the product (i.e. scientific instrument), may actually operate the product (power plant), or may teach the operation to the user (i.e. office building).

Figure 2: Process of Engineering Work Including Offshore Outsourcing (Simpson 2004)

Each step requires the skills and expertise of an engineer in different ways. The final step may require an engineer to operate, teach the operation, or sell a product (Simpson 2004). Design work could be performed by a foreign engineer and then the design could be tested onsite, manufactured offshore, or sent back to the U.S. for testing, additional design work, or manufacturing. Or the product or process could be designed entirely in the U.S. and the design sent abroad to be manufactured and the manufactured product be returned to the U.S. (Simpson 2004).

3.2. Global Virtual Engineering Team Definition

A definition from literature review and project team input was developed. Bell and Kozlowski (2002) started to define teams with the main characteristics that differentiate virtual teams from conventional team (see Figure 3).

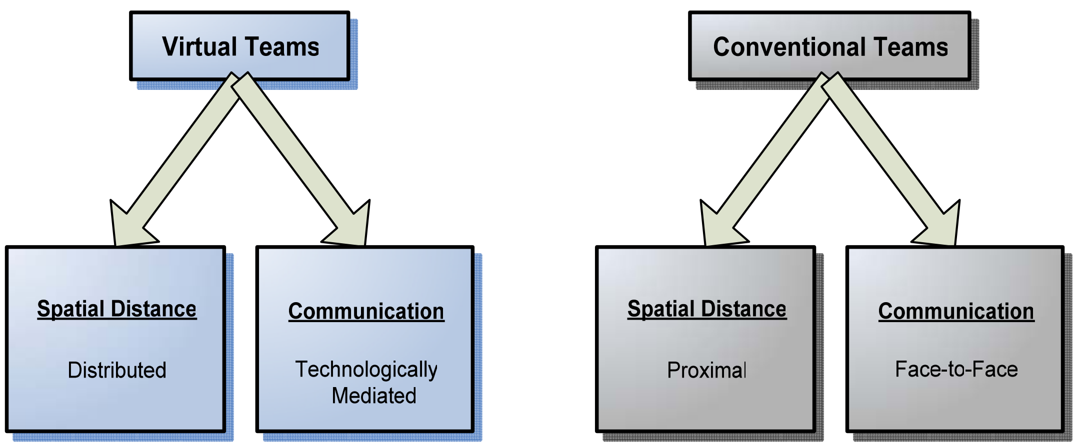


Figure 3: Characteristics that Differentiate Virtual Teams from Conventional Team (Bell and Kozlowski 2002)

The most critical and important feature of virtual teams is that they cross boundaries of space (Bell and Kozlowski 2002). Whereas the members of traditional teams work in close proximity to one another, the members of virtual teams are separated, often by many miles or even continents (Townsend et al. 1996). Although many traditional, localized teams also communicate through computerized communication media, technology such as video conferencing is typically used by virtual team members to supplement their rare face-to-face communication (Bell and Kozlowski 2002). In physically collocated teams, members of the team are likely to have similar and complementary cultural and educational backgrounds since they have gone through the same recruitment and selection procedures as they are employed by the same organization (Pawar 2000). In a virtual team the members may vary in their education, culture, language, time orientation and expertise. There can also be conflicting organizational and personal goals among the members of a virtual team (Pawar 2000).

When determining whether a virtual team is entrained by real time or is distributed across time (see Figure 4), it is important to consider the technology the team employs (Bell and Kozlowski 2002). Certain forms of synchronous communication technologies, such as videoconferencing, allow virtual teams to interact in real time even though great distances and time zones separate team members. Whereas other asynchronous forms of communication technology, such as e-mail, result in greater temporal distribution, even when team members are collocated in time (Bell and Kozlowski 2002). Virtual teams often cross functional, organizational, and/or cultural boundaries. However, the degree to which these boundaries, once crossed, are permeable is expected to depend on the nature of the tasks the team performs. Similarly, the lifecycles of virtual teams are largely determined by the nature of tasks these teams perform. When the tasks a virtual team performs are complex and challenging, the team is expected to more likely maintain a stable team membership and develop a more continuous lifecycle. When tasks are less complex however, a virtual team is expected to be able to function effectively with a dynamic team membership and a more discrete lifecycle (Bell and Kozlowski 2002). The need to develop cohesion and collaboration among team members is minimal and the degree of familiarity among team members is often not critical (Bell and Kozlowski 2002). As the tasks a virtual team is required to perform become more complex and challenging, requiring greater levels of expertise and specialization, a higher premium is expected to be placed on synchronous workflow arrangements and the roles of individual team members will be more likely to be clearly defined, fixed, and singular

(Bell and Kozlowski 2002). Under conditions of low task complexity, however, there is minimal interdependence among team members and more asynchronous workflow arrangements are expected to be adopted. In these situations, virtual team members can hold multiple roles without compromising the effectives of the team (Bell and Kozlowski 2002).

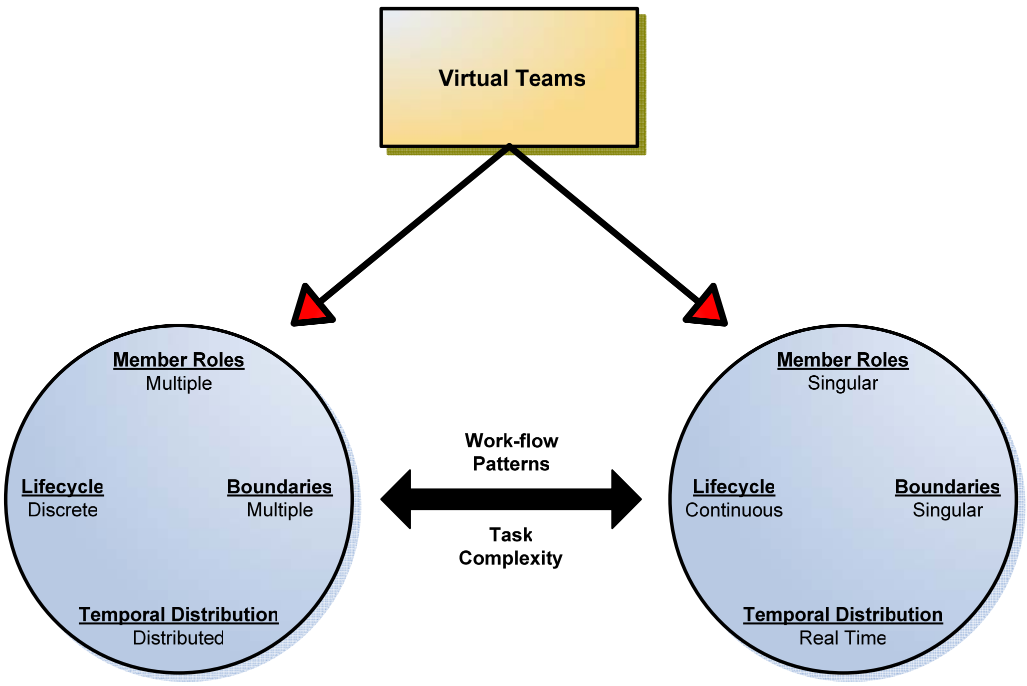


Figure 4: Characteristics that Distinguish Different Virtual Teams. (Bell and Kozlowski 2002)

Townsend et al. (1998) defined virtual teams as “groups of geographically and/or organizationally dispersed coworkers that are assembled using a combination of telecommunications and information technologies to accomplish an organizational task.”

Morris et al. (2002) defined a virtual organization as “an organization constructed of cooperative relationships supported by information technology to overcome restrictions of time and/or location to meet specific objectives.” They further defined virtual teams as “the application of the virtual organization structure at the workgroup level to create temporary teams that may cross functional and organizational boundaries for the completion of a specific task.”

Jarvenpaa and Leidner (1999) defined a virtual team as “an evolutionary form of a network organization enabled by advances in information and communication technology.” Steinfield et al. (2001) defined virtual teams as “teams in which interaction and collaboration takes place among geographically-distributed and often culturally-disparate individuals.” Kristof et al. (1995) defined virtual teams as “self-managed knowledge work teams with distributed expertise that is fluid in terms of membership, leadership, and boundaries (functional, organizational, and geographical).” Kristof et al. (1995) also defined a global VT as “a temporary, culturally diverse, geographically dispersed, electronically communicating work group.” From most of the definitions found, the core aspects of all definitions were similar.

Another very simple definition by Prasad and Akhilesh (2002) defined a global virtual team as “a team with distributed expertise and that spans across boundaries of time, geography, nationality and culture.” Stough et al. (2000) defined the virtual/global/networked team as “a new way of organizing global work forces to harness an information age opportunity for mobilizing hidden manpower through the use of the computer-mediated communication technologies to overcome the barriers created by geographical distance and time.”…. “The virtual team consists of a group of people who collaborate closely even though they are separated by space (including national boundaries), time, and organizational barriers.”

Montoya-Weiss et al. (2001) defined a global virtual team as “a group of geographically and temporally dispersed individuals who are assembled via technology to accomplish an organization task.” Chinowsky and Rojas (2002) defined a virtual team as “a group of people with complementary competencies executing simultaneous, collaborative work processes through electronic media without regard to geographic location.” Global virtual teams are groups that are identified by their organizations(s) and members as a team; are responsible for making and/or implementing decisions important to the organization’s global strategy; use technology-supported communication substantially more than face-to-face communication; and work and live in different countries (Manzevski and Chudoba 2000).

From these definitions combined with feedback from the PT211 team, the following definition was adopted for this study:

> *A Global Virtual Engineering Team (GVET) is a group of geographically dispersed individuals organized through communication and information technologies that need to overcome space, time, functional, organizational, national, and cultural barriers for the completion of a specific engineering task.*

3.3. Global Offshore Outsourcing

The terminology used to describe the exporting of jobs varies widely. Outsourcing is the generic term used when companies contract out certain business functions to an external supplier, eliminating the need to maintain an internal staff necessary to perform that function. Offshore outsourcing is the contracting of these business functions to companies in lower-cost, primarily developing nations (Lieberman 2004). Offshoring is used to describe multinational corporations relocating work from their domestic sites to foreign locations. Lastly, on-site offshoring occurs when foreign companies bring low cost labor using guest worker visas such as H-1B (specialty occupations) and L1 (intra-company transfers) to perform work in the U.S. (Hira 2003).

More firms and owners are sending design work to low cost centers around the world. But the debate grows over quality, security, and patriotism (Rubin et al. 2004). Does offshore outsourcing hurt the U.S. economy by draining away jobs and investment, or does it ultimately make the U.S. stronger? Is it a cost-cutting tactic that should be encouraged, or should it be punished in some way? These are the issues that require additional analysis. Through a literature review, this section aims to present both viewpoints on offshore outsourcing.

Figure 5 illustrate some of the outsourcing trends for the last few years. Data obtained from the Bureau of Labor Statistics shows that for the years between 1999 and 2003, Computer / Mathematical and Architecture / Engineering occupations are said to be the most impacted by outsourcing. For example, Fluor Corporation employs thousands of engineers and draftsmen who work on architectural designs and blueprints in the Philippines, Poland, and India (Lieberman 2004).

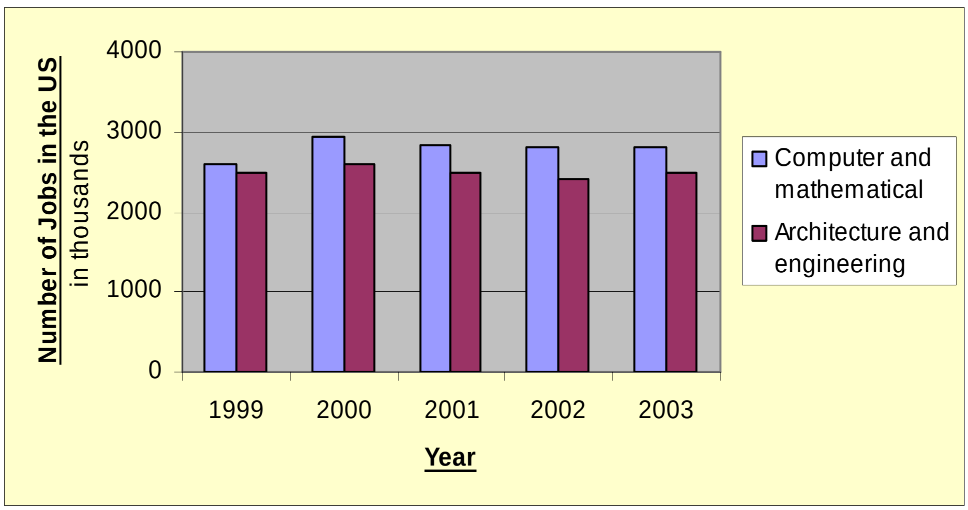


Figure 5: Occupations Identified as Most Impacted by Outsourcing (Bureau of Labor Statistics 2003)

Table 1 includes estimates of the numbers and types of white-collar jobs likely to be offshore outsourced in the years immediately ahead.

Table 1: Projected Numbers of US Jobs to be Moved Offshore to Low Wage Countries such as China, India, Mexico, and the Philippines (Hira 2003)

Profession	By 2005	By 2010	By 2015
Architecture	32,000	83,000	184,000
Business Operations	61,000	162,000	348,000
Computer Science	109,000	277,000	473,000
Law	14,000	35,000	75,000
Life Sciences	3,700	14,000	37,000
Management	37,000	118,000	288,000

3.3.1. Driving Forces

There are many potential drivers for EPC companies to adopt global virtual engineering team strategies for executing projects. They could include innovation, higher labor productivity, more revenue from overseas work, competitiveness, lower wages, ability to work 24 hour schedules, speed-to-market, and availability of specific technical skills. Intense global competition in an environment of slower growth and low inflation demands constant vigilance over costs (Global Insight (USA) 2004). The reluctance of many workers to relocate for a new job, the global nature of the marketplace, the need to complete projects as quickly as possible, and the need to tap the best brains no matter where they may be are all examples of virtual team drivers within and across organizations (Paré and Dubé 1999). The need to appreciate, encourage, and value diversity will be part of the daily routine of doing business around the globe (Noto 1994).

Trade liberalizations in developing countries and the development of critical infrastructure in developing countries acted as a catalyst to offshore outsourcing. The internet has played the largest role in information exchange. Instantaneous telecommunications capacity and affordable high speed computers have enabled digital documents and work to be exchanged instantaneously. Large CAD drawings can be sent through e-mail. Increased phone lines made it possible to hold teleconferences with individuals around the globe (Simpson 2004). Some of the drivers identified from literature review will be described in the following sections.

3.3.1.1. Driven by the Need to Reduce Engineering Service Cost

Corporations are increasingly aware of the availability of large quantities of well educated, motivated, and more affordable labor in foreign countries. Due to the surplus of labor and the low cost of living in developing nations, the labor cost savings can be as high as 90% (Lieberman 2004). Figure 6 shows that some countries engineering wages are equal to only a quarter of a typical US engineer's salary.

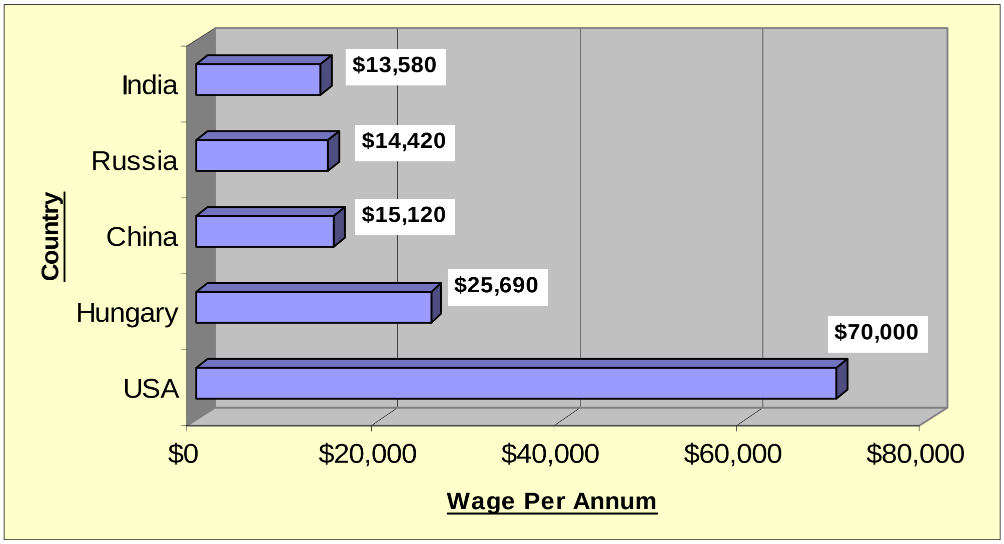


Figure 6: Wage Disparity Between Engineers from Different Countries (McGraw 2003)

While the salaries are significantly different, the savings are not as high due to additional costs including the installation of infrastructure, hiring processes, sending employees abroad to supervise the installation, and negative reactions from the consumer (Hira 2004).

3.3.1.2. Driven by the Changing Education / Demographics

"Job market drives the educational component." Employee education must be carefully considered. Education is definitely a critical item to a nation's economy. If the job market for engineers is declining when compared to that of other areas of expertise, for example business, law or medicine; then the shift in interests of all the prospective engineers are inevitable.

Lower wages do not represent the only competitive threat posed by developing countries, however. U.S. and Germany in particular perform poorly against many offshore locations when it comes to mathematical, scientific and reading skills (Esterl 2004). The international business consultancy cited India as a prime example. In addition to a young, cheap and abundant work force, it noted the South Asian country also "excels in education," producing two million proficient English-speaking graduates with strong technical and quantitative skills each year (Esterl 2004). Figure 7 shows the annual number of engineering undergraduate degrees granted in different countries.

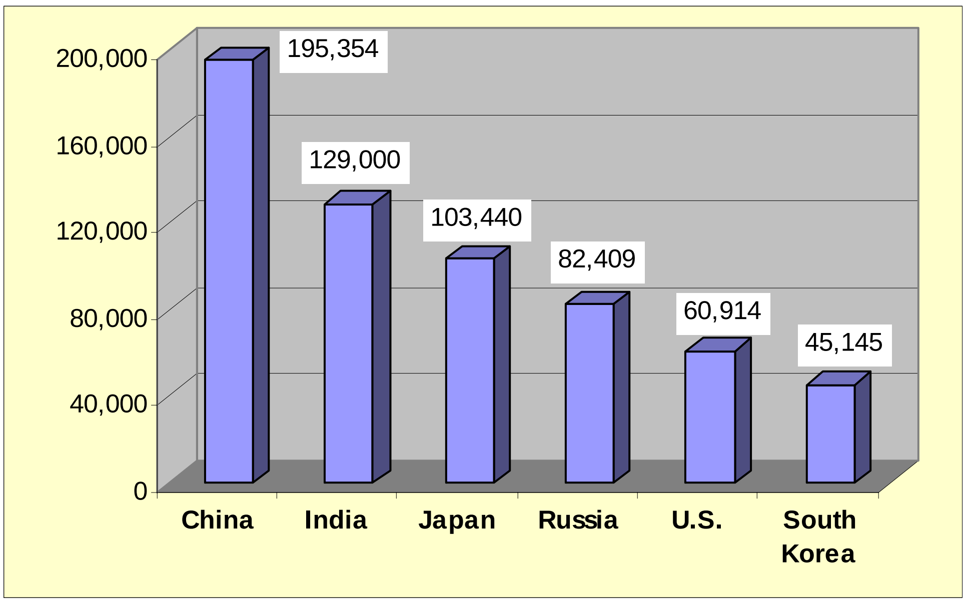


Figure 7: Number of Engineering Undergraduate Degrees Granted Annually
(U.S. Census Bureau 2003)

Table 2 compares recent increases in the numbers of natural science and engineering degrees awarded in countries to which white-collar jobs are being outsourced with similar statistics for the United States. The downward pressure on job opportunities, wages and working conditions that will occur as more and more scientific and engineering jobs are shifted to lower cost offshore locations is likely to reduce the willingness of America's best and brightest young people to pursue careers in science and engineering (Hira 2003).

Table 2: Science and Engineering Degree Production in Selected Countries (Hira 2003)

Country	**BA and BS Degrees**		**MA, MS and PhD Degrees**	
	1989	**1999**	**1989**	**1999**
China	127,000	322,000	19,000	41,000
India	165,000	251,000	64,000	63,000
Philippines	40,000	66,000	255	937
Mexico	32,000	57,000	340	63,000
United States	196,000	220,000	61,000	77,000

3.3.1.3. Driven by Developments in Technology

The increasing technological capability in developing countries is one of the most important events that is driving global companies to realize the possibility of offshore outsourcing of engineering services. This stems from government initiatives and lower cost computer hardware.

Global availability of cost effective, high speed digital internet connections, combined with net based and other communications tools such as email, instant messaging, faxes, videoconferences, and cellular phones have empowered foreign workers to provide services that do not necessarily require direct physical contact. For example, telecom capacity between India or China and the United States grew from 0 to 11,000 Gb/S between 1999 and 2001, while bandwidth pricing is almost nothing (Manufacturing & Technology News 2003). Meanwhile, the cost of a one minute phone call from India to America has dropped by more than 80% since January 2000 (The Economist 2003). Improved bandwidth connections enable the sharing and transferring of large data files on a real time basis.

3.3.1.4. Driven by the Availability of Engineers

The most important economic and strategic drivers behind global outsourcing is the availability of substantial numbers of skilled professionals in other countries who are willing and able to work for much less than their counterparts in the United States

(Hira 2003). A lower wage scale is even more attractive if it comes with a well educated labor force. While U.S. education in math and sciences is eroding, the quantity and quality of labor abroad from which corporations can choose is escalating. For example, with 195,364 engineering graduates in 1999, China graduated three times as many engineers as the United States. Moreover, the engineering graduates represented 44.3% of all undergraduate degrees earned in China. In comparison, engineering graduates accounted for only 5.1% of all undergraduate degrees in the U.S. (NSF 2002). The number of US graduates in engineering and physical sciences is dropping 1% per year (Manufacturing and Technology News 2003). At this rate China is already generating a far larger educated talent pool capable of creating and inventing. As global competition for technical talent intensifies and the number of U.S. born science and engineering graduates continues to decline, the United States will have a difficult time meeting its skill needs.

A McKinsey Global Institute study cites an interesting statistic about the aging U.S. population and the impact on offshoring (Lieberman 2004). To maintain the same share of working age population to total population that existed in 2001, 15.6 million additional workers will be required by 2015. Maintaining U.S. living standards, the study argues, will require more innovation, even-greater productivity gains (including offshoring to countries with more workers), or increased immigration into the United States. Offshoring is seen by many companies as an easier option to consider (Agrawal et al. 2003). The Information Technology Association of America predicts the “skilled worker gap” to reach 14 million by 2020, as Baby Boomers retire and smaller numbers of knowledge workers enter the U.S. work force (Miller 2003).

3.3.1.5. Driven by the Need to Re-allocate Saved Capital to Higher Value Purposes

If we do not look closely at our nation's innovation future, we may suffer in an international economy driven by technology, education, competition, and market access in other countries (Lieberman 2004). This driver allows a company to focus more on their core competencies and free their available resources for higher value purposes, thereby maintaining their leadership in that particular sector. Capital can be saved through offshoring some of the less value added work, e.g., detailed design to other countries. Freeing up resources for more critical work by deploying crucial internal staff on more strategic projects is a driving factor for some enterprises.

3.3.1.6. Driven by Global Customers or Local Customers

Proximity to customers is often essential to compete for service sector business. Many business leaders are attracted to the perceived market possibilities in rapidly developing nations such as China and India, with over 2.4 billion people between them. For example access and proximity to large markets with a combined population of 2.4 billion people, China and India are huge potential markets for U.S. products and services. By moving offshore, corporations can gain regulatory approval, perform market research, and customize their products and services accordingly in a timely manner (Lieberman 2004).

3.3.1.7. Driven by the Need to Reduce the Engineering Schedule

Another reason for multinational corporations to locate their services and Research and Development (R&D) activities in foreign countries is the competitive advantage gained by more effectively working around the clock by using employees in different time zones (Lieberman 2004). Time zones allow corporations to perform design and research work 24 hours a day, 7 days a week while allowing employees to work during their typical work time in different countries. Productivity grows as the work is performed in a regular work day, without the need for overtime pay or shift work.

3.3.1.8. Driven by Country, Client, or Funding Source Requirements

By implementing business friendly policies such as less burdensome taxation, regulation, and litigation environments, foreign countries can provide U.S. corporations with a low-cost alternative for their manufacturing, services, or R&D activities (Lieberman 2004). Foreign nations will continue to work to make their business climates and infrastructures more attractive to global innovation leaders.

3.3.1.9. Driven by Company Policy

This section touches upon a company's policy, for example global procurement of services. Larger engineering companies can set up divisions abroad where they hire foreign engineers to work for their company (Lieberman 2004). Smaller companies or smaller projects are able to be offshore outsourced through consulting companies (U.S. or foreign owned) that facilitate the completion of engineering work. The rising number of international mergers, acquisitions, and collaborations, and improved international protection of intellectual property rights have contributed to the offshoring of activities (Lieberman 2004).

After companies such as GE pioneered the offshoring movement in the late 1990s, many other companies followed and the practice is becoming more standardized (Solomon and Kranhold 2005). Now offshoring is a new management paradigm that corporations are forced to consider to remain competitive (Lieberman 2004). Although offshoring began with large corporations, now that the process has matured, small businesses are taking advantage of it. With the emergence of brokers who locate development centers abroad for U.S. companies, the coordination and management of small projects has become cost effective and efficient (Lieberman 2004). Numerous consultants and outsourcing vendors who facilitate the transition can be located easily at web sites such as www.globalsolutionindia.com, www.outsourcing-russia.com, www.shinetechchina.com, www.outsourcephillipines.org, www.outsource2india.com, and www.outsourceromania.com. New Internet based third party outsourcing auctioneers that reach low cost researchers, engineers, and programmers from all over the world are further contributing to the offshoring of skilled labor. Companies are auctioning their design, engineering, software, and research projects on web sites such as www.projectspool.com where scientists across the globe compete for the work. By posting R&D problems on www.innocentive.com, corporations can solve problems at a low cost with scientists around the globe without the added overhead costs of health and pension benefits (Lieberman 2004).

3.3.2. Perspective on Global Sourcing of Services

Many people have different opinions related to the concept of offshore outsourcing. Understanding various perspectives is very important in today's global economy. The following matter from some of the literature discusses arguments that have been cited in literature to support the advantages and impact of globally sourcing of engineering services.

Baily and Farrell (2004) argue that offshore outsourcing improves the US economy through corporate savings, a better deal for customers, additional exports, repatriated profits, productivity, and new jobs. The most significant benefit is that it lowers corporate costs, which benefits both consumers and shareholders (Lieberman 2004). The cost savings boost corporate profits, raising investor confidence. Offshoring has become a matter of survival for some U.S. corporations who have to compete globally for market share. U.S. revenues grow when offshore providers create new foreign corporate markets for U.S. products such as telecom equipment and computers. As the standard of living improves abroad, new consumers for U.S. products are created.

The main driver of growth in our economy is our prodigious technical change (Aeppel 2004). Technical change nearly always substitutes for unskilled labor, but it creates new skilled jobs, both by creating new products and processes but also because the maintenance of technology also requires skilled labor. Workers freed up from routine tasks that have been outsourced are often redeployed within the company to higher paying jobs, or on projects that generate greater value-added services or products (Bartlett 2004). During one of the interviews for this research, an executive stated that, “some projects become viable due to outsourcing, thereby creating more jobs once the project is complete.”

While there are benefits to global offshoring, proponents often fail to address the related costs (Hira 2003). Some people argue that there are serious, long-term consequences for many Americans, their communities and the nation as a whole. Such adverse consequences identified by Hira (2003) are:

- Loss of employment and income for American professional workers if offshoring continues to exert downward pressure on job opportunities, wages and other forms of compensation;
- Loss of payroll and income taxes at the national, state and local levels at a time when demands on pay as you go social insurance programs, such as Social Security and Medicare, and the need for improvements in our communications, educational, health care and transportation infrastructures are beginning to accelerate;
- Loss of employer contributions to government sponsored unemployment insurance and worker’s compensation programs that will be needed to help sustain the increasing numbers of displaced workers whose jobs have been moved offshore;
- Loss of national economic and technological competitiveness and increasing dependence on foreign sources of supply for consumer products, military hardware and defense systems as well as the technical talent needed to design, produce and maintain them; and
- Further imbalances in international trade and the US balance of payments as America is forced to buy more products and offshored services than it sells to its major trading partners.

Some of the views against offshore outsourcing as found in literature stated that if technology jobs are outsourced due to domestic supply constraints, the mechanism for expanding domestic supply is short-circuited. For example, if a shortage of nurses is met by importing foreign nurses under a visa work program, domestic nursing schools are unlikely to increase their enrollments (Aeppel 2004). The primary downside to outsourcing perceived by American businesses is a loss of institutional knowledge, data security, loss of intellectual property rights, and political risks. A Gartner research (2004) study showed that companies refrained from offshore outsourcing due to "concerns over security, the viability of providers, and service quality…there are also political risks in terms of instability in foreign nations and market risks of a consumer backlash against off shoring companies."

America may face serious negative consequences from offshoring. Offshoring of high-tech jobs threatens our national security, exerts downward pressure on high skill wages, and diminishes our tax base (Lieberman 2004). The obvious immediate impact of offshoring is the loss of jobs for American workers. Unlike in previous years when international competition adversely affected American corporations, this time it is the workers who are left exposed while corporations benefit from offshoring (Hira 2004). As firms export critical business and technical knowledge, they risk losing core competencies, in house expertise, and future talent. Offshore outsourcing of high skill jobs to foreign nations may mean handing over to foreign nation's future innovations that are the direct result of knowledge gained by solving technical problems during manufacturing, design, research and development (Lieberman 2004). A nation's investment in R&D is an indicator of its future economic health. In spite of ongoing globalization over the past several decades, some argue that the United States has been able to maintain a healthy economy due to its leadership in innovation. This can be attributed to the United States' considerable R&D investment in high technology industries such as computer systems design and related services, software, communications, semiconductor and electronic components. Innovation in high technology sectors drives economic growth by creating high value jobs, boosting productivity, raising wages, providing international competitive advantage, and producing the next generation goods and services. Increased efficiency and productivity derived from advanced materials, tools, and processes generated in high technology industries strengthen other industries, ranging from construction to finance. A continued shift in design and R&D to foreign countries puts all these economic benefits at risk, not to mention may have unintended political and security consequences (Lieberman 2004). Personal economic and national security will be subject to increasing risk as responsibility for more and more private, proprietary and mission critical military and national security data is transferred to other countries.

The following outlines the Engineering Societies' Perspectives: Engineering societies are charged with protecting the interests of their members. Many of these organizations have taken a stance on offshore outsourcing. The membership of the National Society of Professional Engineers, NSPE (consisting of licensed, professional engineers) has made the following statement regarding offshore outsourcing (NSPE Issue Brief 2004):

- Outsourcing of engineering work should be done only when the talent cannot be found in the United States.
- If outsourcing of engineering work is done, it should be done using the same rules, regulations, laws, and ethical codes that employers and employees are subject to in the U.S.
- The engineering work should be performed without jeopardizing national security, and all parties should be made fully aware of the location and the conditions of where offshore work is being performed.

3.4. Key Players in Offshore Outsourcing

India is one of the primary countries that is used as a source for low cost engineering services. Despite the recent growth, India's telecommunication infrastructure still needs to be improved (Lieberman 2004). India still struggles with low telephone and internet access rates, and state owned companies dominate the telecom services market. Its economic stability and political climate are also high risk factors, considering the rising tension between India and Pakistan. Some of the reasons for India being a key player are as follows (Dham 2004):

- Large English speaking local talent pool,
- Good engineering institutions including IITs, and Regional Engineering Colleges,
- The wage rate is low (as much as three times less than U.S. or European rates),
- Experienced Indians from the U.S. are increasingly willing to return to India, and
- There is a large pool of dedicated hard working engineers with increasingly better skills.

China is another potential source for offshoring engineering services. However, China's political climate and weak English language skills are significant risks for corporations (Lieberman 2004). One key concern with China is the poor intellectual property rights protection (IPR). Other potential countries for engineering service sourcing include the Philippines, Malaysia and Russia.

3.5. Global Virtual Teaming

The infrastructure to support virtual teams must not be 'designed by doing' but rather must be carefully organized, planned, and executed (Wilczynski and Jennings 2003). Prasad and Akhilesh (2002) proposes that global virtual teams be designed with a holistic approach considering an optimal fit between the team structure and the key impacting factors such as objectives, work characteristics and situational constraints to deliver performance (see Figure 8). Prasad and Akhilesh (2002) proposed a model for global virtual team performance (see Figure 9). This model shows that the team structure is impacted by strategic objectives, work characteristics, and performance constraints.

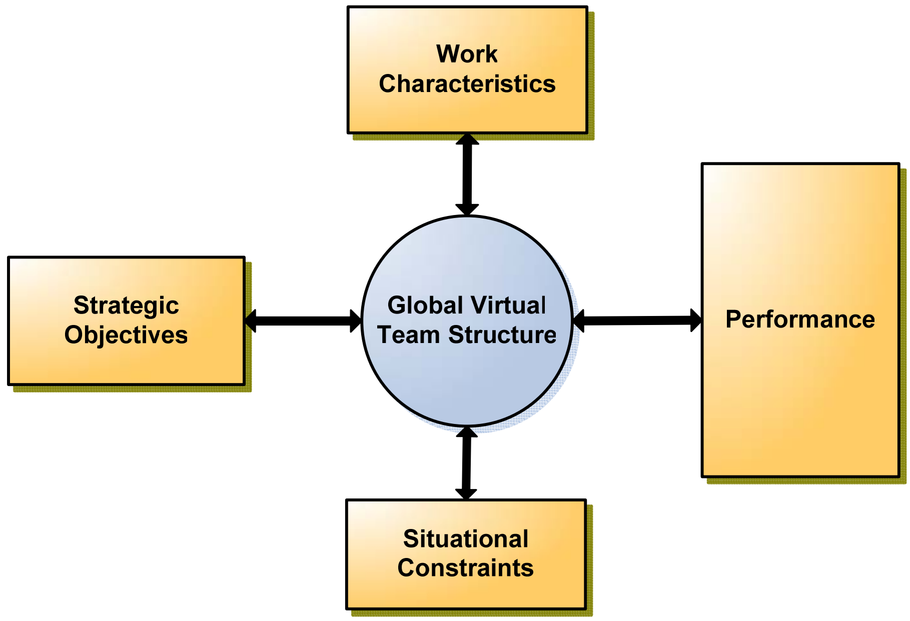


Figure 8: Global Virtual Team Framework (Prasad and Akhilesh 2002)

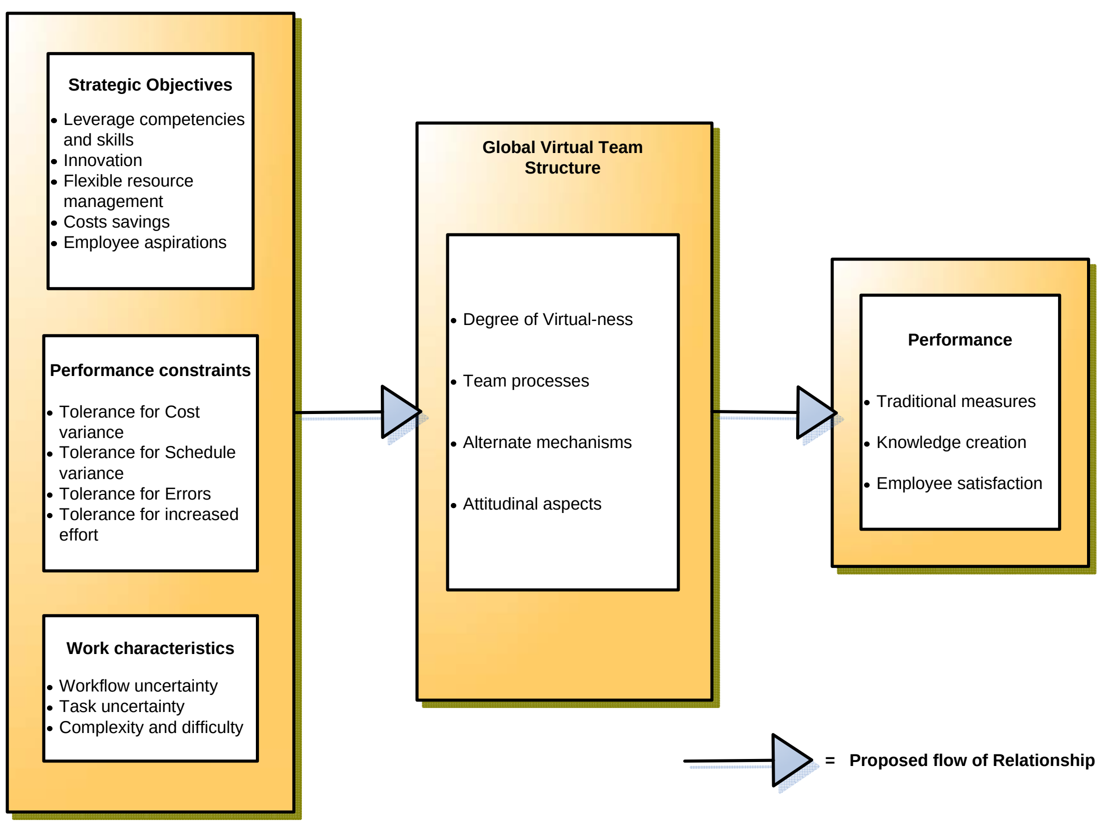


Figure 9: Global Virtual Team Performance Model (Prasad and Akhilesh 2002)

Various sources, along with results from interviews have identified technology; management; organization; project control; and team communication as important items to consider in global virtual team formation and execution. Each is covered in more detail in the following sections.

3.5.1. Technology

Important items related to technology include setting up an adequate network, identifying standard applications (e.g., standardized collaborative file management software, CAD design software), identifying appropriate communication tools, etc. There are five interdependent factors critical to deploying collaborative technologies; consider a technology's availability, reliability, capability, supportability, and an individual's ability to use the technology (Klein and Pena-Mora 2002). Key technological barriers include the underdevelopment of a telecommunications infrastructure; the high cost of using such services; the demands on expert time in upgrading the systems; and the rapidly growing expectations of users (Kimble et al. 2000).

Technologies can be categorized into three (Chinowsky and Rojas 2002):

1. *Communication Technologies*: These permit individuals to transmit thoughts either synchronously or asynchronously, but do not permit sharing of common data or data manipulation (e.g., e-mail, fax, telephone or teleconferencing).
2. *Cooperation Technologies*: These permit individuals to access a shared data repository, but do not have the ability to manipulate the data in a shared, real time experience. The manipulation of the data is restricted to asynchronous access, manipulation, and posting.
3. *Collaboration Technologies*: These permit the capability to visually and orally communicate in addition to the synchronous, real time manipulation of data.

The following technology features were recommended by Chinowsky and Rojas (2002):

1. Select the appropriate technology before embarking on a virtual team implementation effort;
2. Determine security requirements for project communications;
3. Determine level of security required for document transmission;
4. Establish interoperability requirements for each project member; and
5. Publish project data standards for all the project personnel to ensure consistency throughout the project.

Exchanging documents; decoding and encoding; transferring graphical images in various formats; accessing web sites; and using chat facilities are examples of technology usage that increases over time (Igbaria and Tan 1998). Management should plan for the varying interfaces, test the technology ahead of time, and provide adequate technical support as the work becomes more complex.

Chinowsky and Rojas (2002) concluded with the following statement: "Technology is not the barrier to successfully implementing virtual teams – although technology can lead to virtual teaming failures, sufficient technology is available to successfully implement virtual teams. Rather, revising traditional management practices is the key to successfully initiating and implementing virtual teams."

3.5.2. Management

While traditional wisdom on forming and leading on-site teams also applies to a globally dispersed team, managing the latter requires more extensive discipline and attention to details because there are fewer opportunities for informal or ad-hoc interaction (Klein and Pena-Mora 2002). Managers responsible for virtual project teams need to align the communication structure to the task characteristics (Ahuja and Carley 1998). For routine tasks, a hierarchical structure may be preferable, because hierarchies provide efficiency and economy of communication. Managers can foster a hierarchical communication structure by promoting specialization in knowledge areas so that all communication regarding a particular area is directed through a single individual. On the other hand, complex tasks should be managed to promote plenty of discussion and decentralized decision-making (Ahuja and Carley 1998).

Effective communication becomes an area of immediate concern for the global project manager (GPM) as he recognizes the communication requirements, adjusts to this environment, and evolves a process to convey the proper message (Guella 1996). Meeting customer expectations, developing high performance teams, communicating, and controlling costs with a geographically dispersed and culturally diverse team are some of the challenges facing a GPM. The success of virtual teams is heavily dependent on the preparation of the project leaders. The categories of effective leadership skills in virtual project team or distance management situations identified by Thompsen (2000) are: communicating effectively and using technology that fits the situation; building community among project team members, based on mutual trust, respect, fairness, and affiliation; establishing a clear and inspiring shared purpose, vision, goals, and expectations; leading by example with a focus on visible, measurable results; and coordinating and collaborating across organizational boundaries.

Managing global projects with virtual engineering teams presents many interesting and challenging situations. Important project management knowledge areas are: integration, scope, time, cost, quality, human resources, communications, risk and procurement management (Gezo et al. 2000). Strategies such as developing practical performance metrics, increasing visibility with frequent deliverables, prototyping and early integration, and defining project reporting mechanisms have been proposed as ways of monitoring remote workers successfully (Paré and Dubé 1999). An understanding of the economic issues (costs & benefits) of whether to decide on the use of a global engineering team is required by decision-makers. They should consider both the long term benefits and costs along with the short term benefits and costs.

3.5.3. Organization

Increased international competition and the rapid pace of technological change are favoring organizations that are lean, fast, and flexible (Miles 1989). Organization issues such as business relationships are an area that requires careful consideration while adopting the services of a global virtual engineering team. A significant amount of research has been performed on team structures and it has attracted researchers from areas of organization design, organizational theory, organizational development and strategic management. A generally accepted, yet a simple, definition of structure is that it is an instrument to achieve the objectives. The most visible and facilitating aspect of teams is their structure (Prasad and Akhilesh 2002).

Trust, social interaction, and group performance were the issues that moved to the forefront of concern as organizations struggled to adapt to the introduction of virtual teams as integral components of organization process (Strauss & McGrath 1994). Cohesion is an important aspect of the virtual team (Powell et al. 2004). While virtual teams begin with lower cohesion, over time, virtual team members exchange enough social information to develop strong cohesion (Chidambaram and Bostrom 1993).

The virtual organization is put forward as a low-cost, highly responsive, adaptable, and flexible way to organize and compete in the face of extreme turbulence and uncertainty in the modern business environment (Marshall et al. 2001). The essential characteristics of the virtual organization have been argued to be:

- Adaptability, flexibility and responsiveness to changing requirements and conditions;
- Effectiveness in utilization of resources;
- Formulation of business alliances of varying degrees of permanence;
- Dispersion of component parts;
- Empowerment of staff;
- Stewardship of expertise, know-how, and knowledge (intellectual capital);

- Low levels of bureaucracy;
- Opportunistic behaviors, embracing change and uncertainty; and
- High infusion of IT to support business processes and knowledge workers.

A well defined team structure helps each individual identify the work that must be performed, and it helps the team understand how different groups and tasks share precedence, coordination, supervision and rework interdependence throughout the project. The nature and amount of required coordination work, however, may vary considerably, depending on how the project team is organized—centralization, formalization, task assignment, decision-making policy, available communication tools, team experience (Kunz et al. 1998).

3.5.4. Project Control

This section addresses the more project specific information such as the identification process of team members with global virtual teaming competencies, monitoring progress and performance of the design team, familiarizing members with work process and culture in other foreign location, etc.

Institutions can be defined as relatively stable collections of practices and rules defining appropriate behavior for specific groups of actors in specific situations (March and Olsen 1998). They consist of informal (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights) (North 1990). According to North (1990), the major role of institutions in a society is to establish a stable (but not necessarily efficient) structure to political, economic and social interaction (Tukiainen et al. 2004). On the one hand, it is argued that the heterogeneity of worldviews in a project organization increases the diversity of available resources, thus bringing more creativity into problem solving. On the other hand, diversity increases complexity and the possibility of ambiguity and suspicion, which might prove to be problematic with regard to group effectiveness in global projects.

Project management is now taking place in a global arena (Bauhaus and Lamy 1996). The extended scope of global business now requires project managers to work with team members whose approaches to project and people issues vary according to their culture. The project manager needs to add cultural competence to his core competencies. Cultural competence is knowing how to use cross-cultural sensitivities and skills to cope with cultural differences that can cause miscommunication in the international workplace (Bauhaus and Lamy 1996).

3.5.5. Team Communication

Developing a team culture and common communication procedures are essential for the development of credibility and trust among team members in a virtual environment (Kimble et al. 2000). An improvement in relationships between the parties is likely to improve communications more effectively than any changes in communication techniques (Higgin and Jessop 1965).

Details in planning or organizing communication between the team members that are in collocated offices and also remote offices must be considered. The first step to leading a project team is to recognize and appreciate the cultural differences in any international team (Mar-Yohana 2001). Successful global managers and team members clearly have a process of interaction with cultural differences that underlies everything they do in fulfilling global projects. A summary of these strategies outlined by Bauhaus (1995) are:

1. Successful global participants have highly developed listening skills;
2. The global participant always considers if there is a cultural component involved;
3. The global participant has a proactive approach in looking for understanding;
4. The global participant creates a sense of confidence and respect in the team through respecting differences;
5. The global participant sees the importance of personally experiencing the other environment and seeks ways to do that;

6. The global participant takes time to relate and connect;
7. The global participant understands the difficulty of speaking in a language not your own;
8. Global participants can characterize their own culture so they know what the other cultures are seeing;
9. The global participant is constantly learning how to be effective in the face of all difference; and
10. Global participants have learned how to fulfill the task at hand at the same time they are culturally sensitive.

3.6. Summary

An essential component of the rising use of virtual teams is the geographical distribution afforded by the globalization of businesses as well as the availability of inexpensive, advanced information and communication technologies (Evaristo 2003). Companies use GVETs for different reasons. Based on the contractual arrangement, companies may be involved with cost driven or schedule driven projects or even both. For example, in a fixed lump sum contract both cost and project completion time are the key requirement to a successful project. The drivers for a cost reimbursable type contracts could be different. The need to be closer to the project location can also drive companies in the use of GVETs. Some overseas countries may also have a law that calls for certain percentage of local content requirement on any projects setup on their shores.

To date, there has not been a published study based on extensive research that analyzes why companies are using global virtual teams for projects. This research aims to further investigate and rank the drivers in the EPC Industry. Companies face many challenges during the GVET utilization on their projects. Some of the challenges are in the initial formation of an offshore office; splitting the scope of work; technology, communication, and management challenges; quality control; and cultural issues. Some of the risks that companies may get exposed to during the

GVET utilization are intellectual property, competitive vulnerability, partner instability, and political instability of the overseas country. This research aims to capture the most important practices performed by companies in the EPC Industry.

CHAPTER 4

DATA COLLECTION, ANALYSIS AND RESEARCH RESULTS

GVET implementation is still in its infancy within the EPC Industry. From the data collected during this research, it is clear that this is an area of significant interest within the EPC Industry. But there is still a long way to go to reach full implementation. The data collection phase in this chapter was to determine the GVET concept within the EPC Industry. The focus was on identifying the driving forces, current application of GVET in the EPC Industry, determining the expected future use of GVET, and success / failure factors.

The CII membership was selected for this research undertaking because of the cross-section of owners and EPC organizations that are found within the group. To assist the respondents in replying to the survey, an electronic form of the survey was developed and posted online. The address to this online survey was then sent to the CII contacts through electronic mail with the research overview and a request for participation. The respondents were given two weeks to respond to the effort at which time a follow-up request was submitted by electronic mail.

The results from the survey effort provide a snapshot of current GVET practices within the EPC Industry. The following charts highlight notable responses from the study as well as an overview of the results. The complete survey and responses are provided in Appendix C.

4.1. Data Collection and Survey Results

Table 3 shows the summary of the data collection for this study. 46 responses were received for the online survey of which 59% of the respondents were from the EPC organization and 41% were from the Owner organization.

Table 3: Data Collection Summary

Data Collection		
Survey		
Number of responses	Owner	19
	EPC	27
	Total	46
Note: – *CII member companies: 33 (Owner=13, EPC=20)* – *Non-CII companies: 1 (Owner=0, EPC=1)*		
Interviews		
Number of interviews performed	Domestic	17
	Foreign	4
	Total	21
Detailed Case Study		
Number of Case Study	1	

A total of 21 interviews; 17 domestic and 4 foreign office interviews in Czech Republic, Romania, United Kingdom, and India were performed for this research. The interviewed executives had the following position titles: Manager, President, Vice President, Chief Technical Officer, Director of Design, Senior Project Manager, Project Leader, Quality Assurance Director, Offshore Engineering Coordinator, Senior Project Engineer, Engineering Manager, Technology Director, and Engineering Director.

The statistical analysis of survey responses were analyzed based on single-variable statistics. This method identifies the frequency of each response. Both the frequency distribution and percentage distribution are shown for the results of most of the questions in the survey. The driving factors are analyzed by a weighted average statistical method. All the results analyzed from the survey questionnaire are separated into two categories; Owner organization and EPC organization.

4.1.1. Ranking of Driving Factors

Identifying the driving factors was one of the key features towards an effective understanding of the GVET concept. The goal of this section was to better comprehend the reasons why companies within the EPC Industry are adopting GVET strategies on their projects. Table 4 shows the summary of drivers ranked in decreasing order of importance. To better realize both perspectives of the Owner organization and EPC organization, the results are separated. It was interesting to note that both types of organizations had different reasons and priorities for implementing GVETs. The need to reduce engineering service cost was the only driver that was common in both the organizations ranking. Then a total weighted average of all the responses was calculated to identify the final order of the driving factors.

Table 4: Summary of Drivers Ranked in Decreasing Order of Importance

Drivers	**Owner**	**EPC**	**Total**
	Rank	Rank	Rank
Driven by the need to reduce engineering service cost	1	1	1
Driven by competitors	7	2	2
Driven by global customers or local customers	6	3	3
Driven by the need to locate services close to the project location	2	7	4
Driven by the need to reduce the engineering schedule	4	6	5
Driven by the goal to expand detailing work for the same cost	5	8	6
Driven by country, client, or funding source requirements	9	5	7
Driven by the need to understand/comply with codes and standards	3	12	8
Driven by company policy, e.g., global procurement of services	10	9	9
Driven by the need to balance engineering workload among multiple offices	15	4	10
Driven by developments in technology	12	11	11
Driven by the availability of engineers	13	10	12
Driven by the need to improve engineering quality	8	14	13
Driven by the need to maintain consistency of product/service	11	13	14
Driven by the changing education/demographics	14	15	15

4.1.2. Summary of Survey Responses

The first section of the survey centered on the experience level of GVET application within the surveyed companies. Figure 10 shows the distribution of responses related to how many years of personal experience the respondent has with GVETs. Figure

11 illustrates the company's experience level. The chart clearly indicates a majority of both owner respondents and EPC respondents already have significant amounts of personal experience with GVETs. It was the same case with the company experience as well. It is interesting to note that there are significant differences between Owner and EPC with respect to zero experience and more than five years experience. It is clear that GVET is a newer concept for Owner organization than for the EPC organizations.

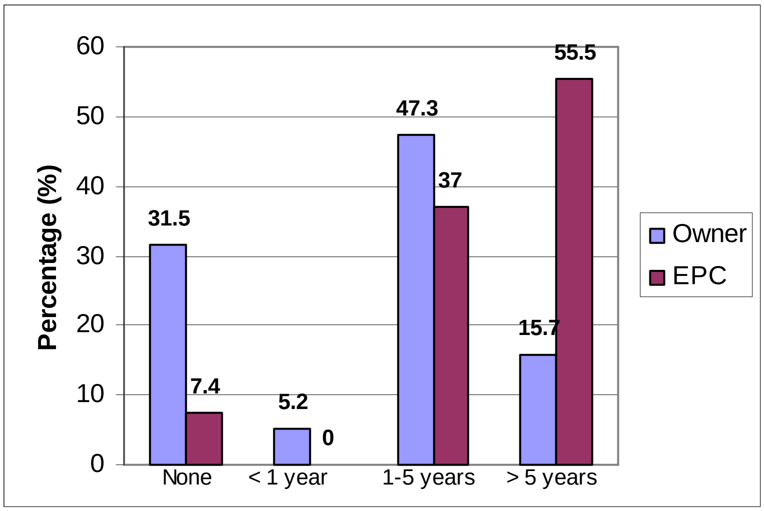


Figure 10: Personal Experience with GVETs

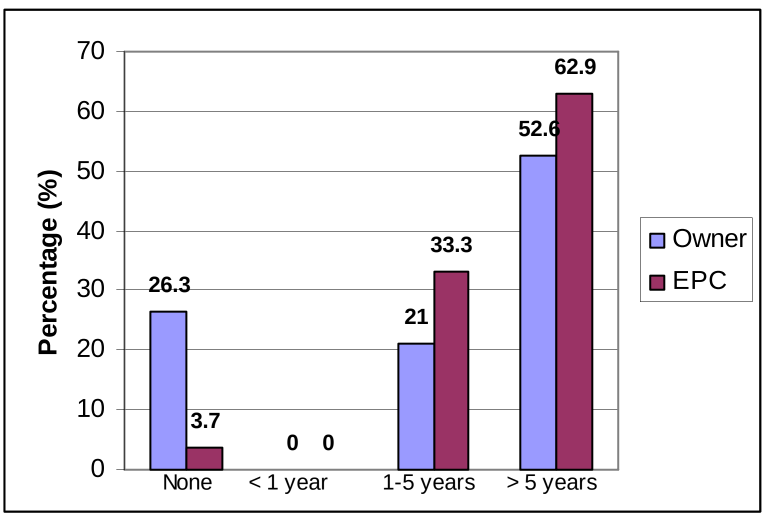


Figure 11: Company Experience with GVETs

Figure 12 shows that more GVETs are utilized for larger sized projects. This may be due to the reason that initial investment is required for setting up GVETs for any project and it is not always economical to implement GVETs on small projects. But, it is interesting to note that 40.7% of the EPC organization still uses GVETs for smaller sized projects. This could mean that through more experience and alliances with well established Low Cost Engineering Centers (LCECs) or High Value Engineering Centers (HVECs), companies do not require as much investment for initial GVET setup expenses.

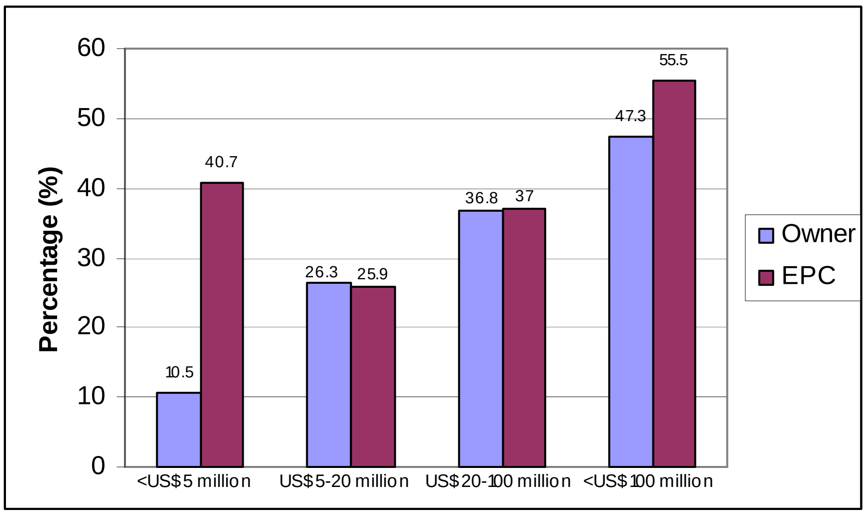


Figure 12: Size of Projects Executed with GVETs

The results of the question in Figure 13 clearly indicate that GVET is a common application, with only 26.3% of the owner and 7.4% of the EPC respondents indicating that they are not using a GVET for any projects. Another interesting element to the response to this question was that there were 5.2% of the owners and 7.4% of the EPC organizations that use GVETs on all of their projects.

Another result of interest focused on the split of the engineering work. Figure 14 shows how the companies divide the scope of engineering work performed by GVET on typical projects. By comparing the results for both Owner and EPC there was a higher rate from the EPC for dividing the scope of the engineering work by a vertical split. Almost 58% owner respondents and 74% EPC respondents indicated that they split the work between project phases (schematic design, design development, detailed design, etc. Similarly there was a higher percentage from the EPC for the scope of work being split horizontally. A similar split percentage was found for work split between project components and/or systems (horizontal split). It was interesting to note that around 37% responded indicating that the engineering was integrated within all groups.

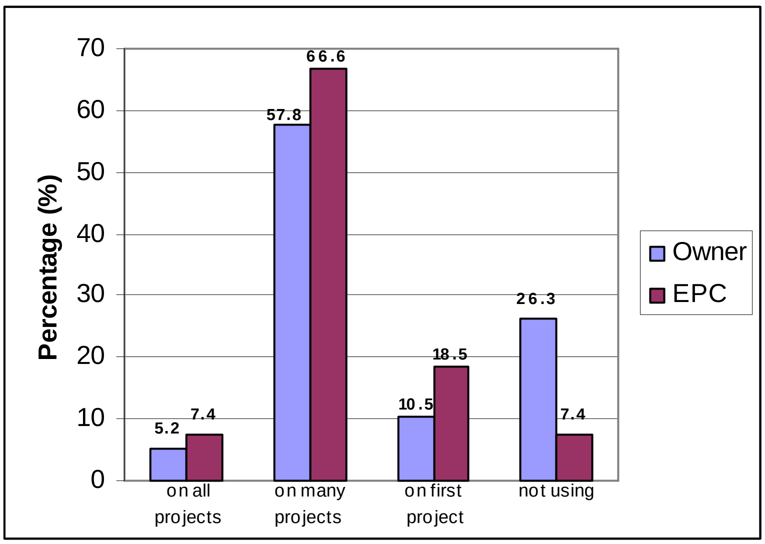


Figure 13: Frequency of Company Use of GVETs

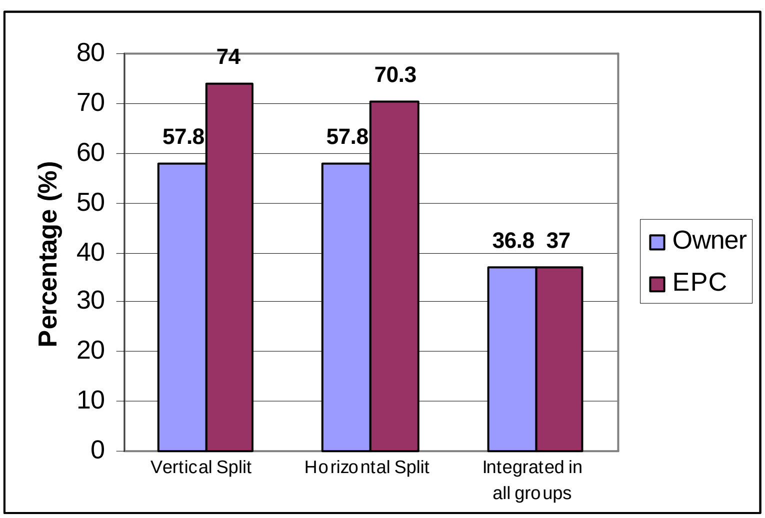


Figure 14: Scope of Engineering Work Performed by GVETs

Table 5 compares the viewpoint of both the owner and the EPC organization regarding typical impact on engineering cost, construction cost, engineering time, overall project delivery time, engineering quality, and construction quality. It is interesting to note that almost half of the respondents stated that more than 10% reduction in engineering cost is achieved through using GVET. Another observation was that the majority were of the opinion that there wasn't any major impact on the other five project performance metrics when projects were performed with GVETs. For example, Table 5 shows that 71.4% of the Owner respondents and 79.1% of the EPC respondents felt that there was no impact on the construction cost while utilizing GVET on their projects. 57.1% of the Owner respondents and 40% of the EPC respondents felt that there was no impact on the engineering time during GVET implementation. A majority of the respondents agreed that there was no impact on the overall project delivery time. Similarly, 57.1% of the Owner respondents and 72% of the EPC respondents experienced no impact on the engineering quality. Also, 64.2% of the Owner respondents and 79.1% of the EPC respondents indicated that there was no impact on the construction quality while utilizing GVET on their projects.

Figure 15 shows that only 14.8% of the EPC organizations did not have permanent domestic and overseas engineering design offices participating in global virtual teaming.

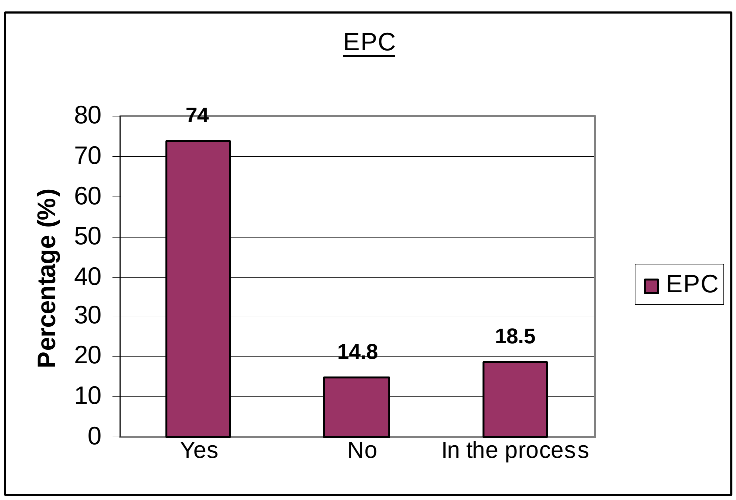


Figure 15: Offices Participating in Global Virtual Teaming

Table 5: Typical Impact on the Project Performance Metrics

	OWNER					EPC				
	more than 10% increase	0-10% increase	Same	0-10% reduction	more than 10% reduction	more than 10% increase	0-10% increase	Same	0-10% reduction	more than 10% reduction
ENGINEERING COST	7.1	0	7.1	35.7	50.0	0	3.8	7.6	42.3	46.1
CONSTRUCTION COST	0	7.1	71.4	14.2	7.1	0	0	79.1	20.8	0
ENGINEERING TIME	0	7.1	57.1	28.5	7.1	4.0	28.0	40.0	20.0	8.0
OVERALL PROJECT DELIVERY TIME	0	14.2	57.1	28.5	0	0	4.0	60.0	32.0	4.0
ENGINEERING QUALITY	7.1	14.2	57.1	21.4	0	4.0	8.0	72.0	16.0	0
CONSTRUCTION QUALITY	0	21.4	64.2	14.2	0	4.1	16.6	79.1	0	0

Figure 16 illustrates that 73% of the EPC respondents and none from the owner indicated that the home country governmental policy and regulations limited their ability to use GVET. Figure 17 shows that 40.7% of the EPC respondents indicated a decrease in engineering productivity when performing projects with GVET in comparison to similar projects performed in the domestic environment. The estimate ranged from 40%-5%. It was also interesting to note that 18.5% of the respondents felt there was an increase in engineering productivity through GVET. Here the estimates ranged between 35%-10%.

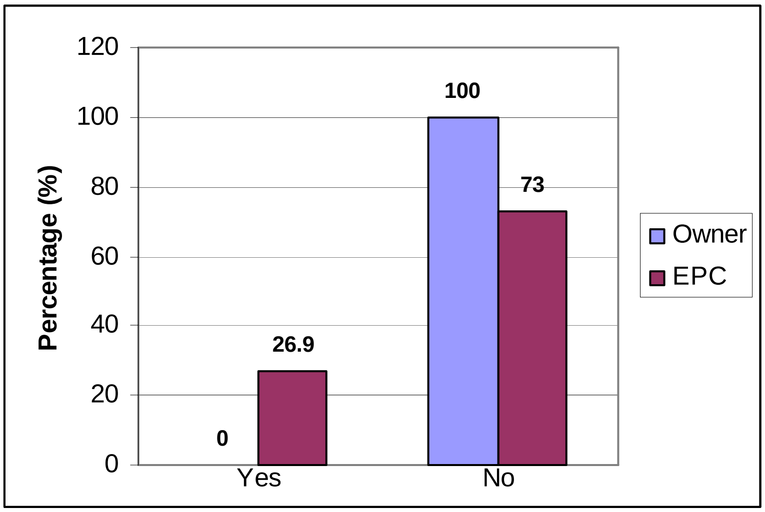


Figure 16: Home Country Governmental Policy and Regulations Limiting the Use of GVETs

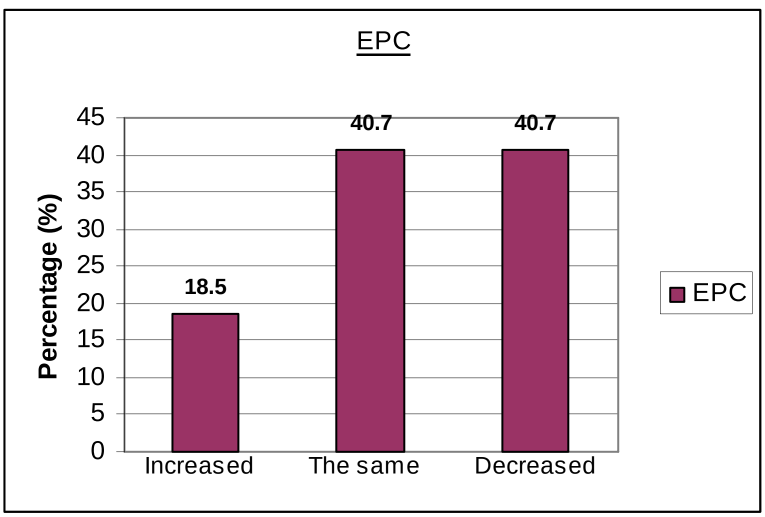


Figure 17: Engineering Productivity Impact

Figure 18 show that 57.6% of the EPC respondents did not have difficulty in satisfying the owner’s requirements with GVET. The EPC organizations strive to achieve a seamless deliverable to the Owner organization while utilizing GVETs. It is essential that the decision to adopt a multi-location project execution strategy be taken prior to the award of the project with the client ‘buying-in’ to the strategy (Levene and Purkayastha 1999).

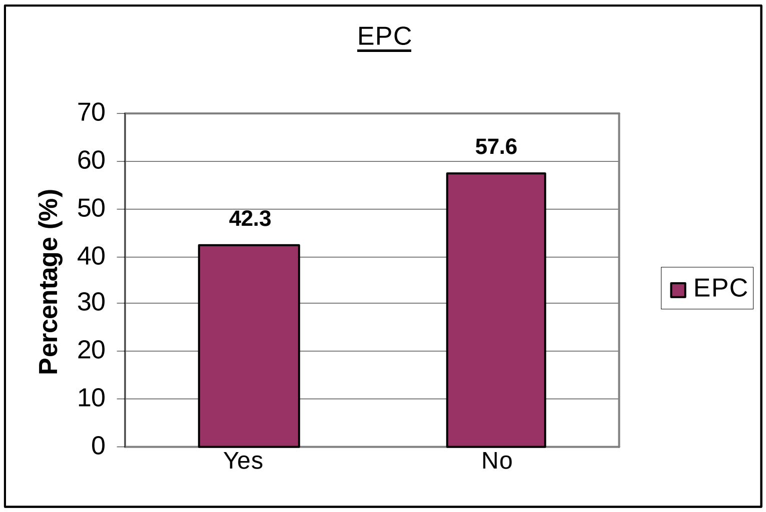


Figure 18: Difficulty to Satisfy the Owner’s Requirements with a GVET

Figure 19 demonstrate almost 53% of both owner and EPC organizations responded to not having frequent language problems on a project. As displayed in Figure 20, the majority of the survey respondents stated that they did not face difficulties meeting P.E. licensing work supervision requirements frequently. However, 11.5% and 7.6% of the EPC respondents indicated that they face frequent problems or no problems at all in meeting P.E. license requirements respectively.

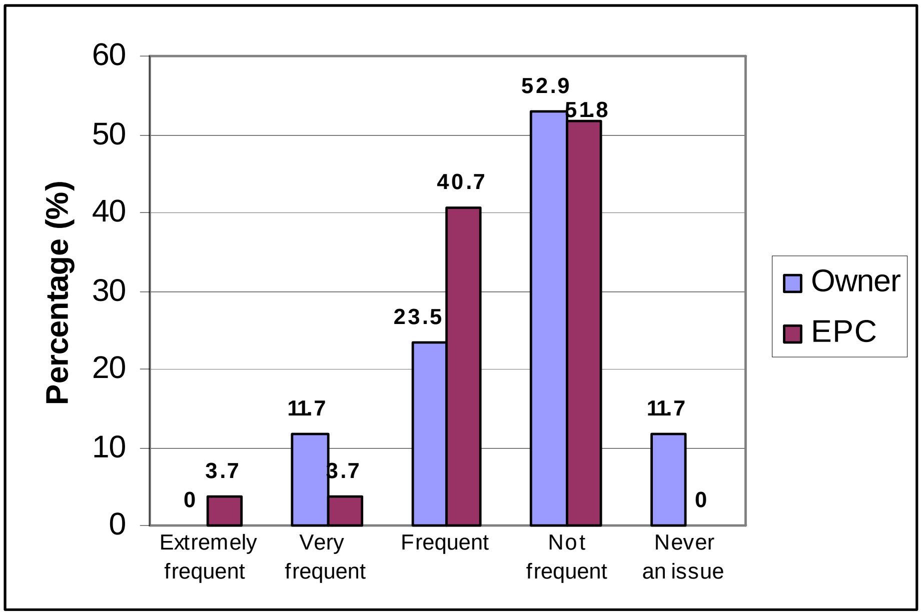


Figure 19: Summary of Language Problems on a Project

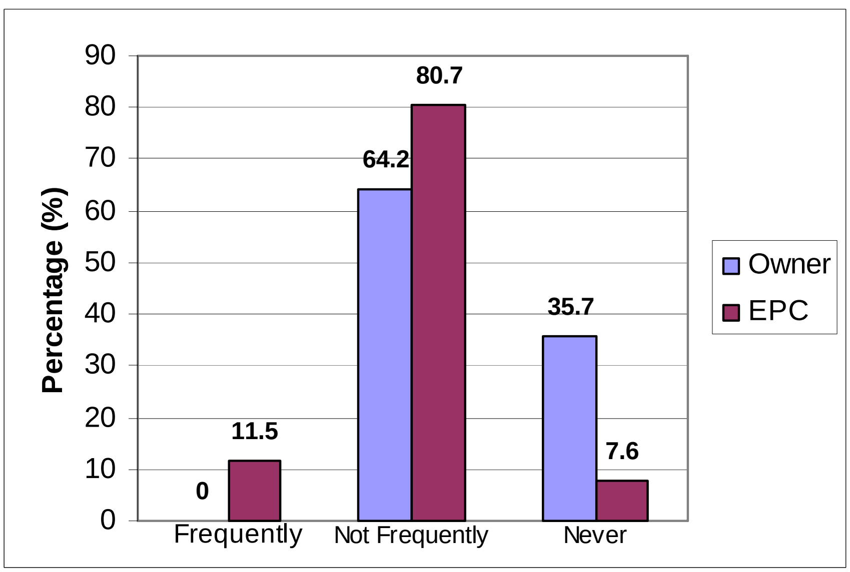


Figure 20: Difficulty Meeting P.E. Licensing Work Supervision Requirements

A question was asked whether technology frequently limits VT implementation. 64.7% and 53.8% of the owner and EPC respondents said that adequate technology is readily available (see Figure 21).

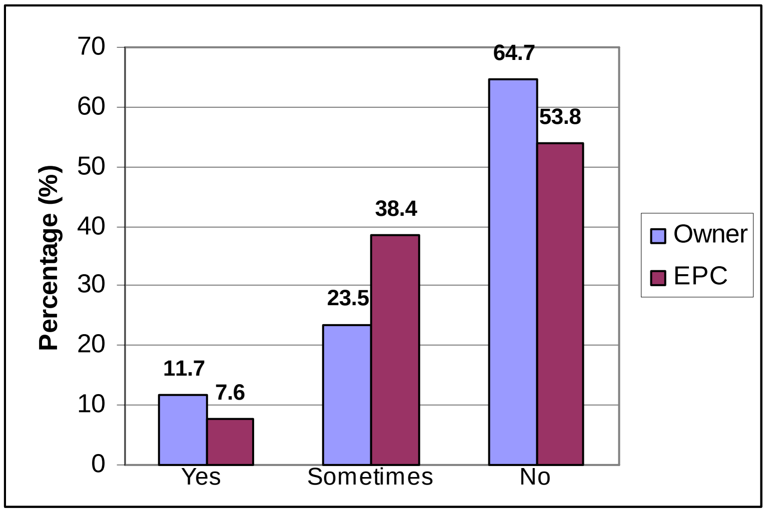


Figure 21: Summary of Technology as a Major Concern for GVET

A section of the survey focused on the tools that companies use during GVET implementation. Table 6 shows the comparison between owner and EPC organization responses regarding the tools used for administering GVETs. They are represented based on percentage of tool usage. As illustrated in Table 6, both the Owner organization and EPC organization most commonly used email, common repositories for project information, video-conferencing, and project specific websites for administering GVETs.

Table 6: Summary of the Tools that are Currently Used for Administering GVETs

Tools Used By Company	Percentage	
	Owner	EPC
E-mail	93.7%	100%
FTP	31.2%	59.2%
Video-Conferencing	68.7%	77.7%
Web-Conferencing	62.5%	55.5%
Virtual Private Networking	25.0%	59.2%
Project Specific Websites	62.5%	81.4%
Applications for Simultaneous Remote Collaboration	31.2%	62.9%
Common Repositories for Project Information	87.5%	74.0%
Knowledge Management Systems, e.g., lesson learned databases	37.5%	66.6%

The subject of security / firewalls received considerable attention during initial research. Specifically, it was found that numerous individuals had experienced difficulties with collaboration tools as a direct result of firewalls either in their organization or in organizations that they were attempting collaboration. Table 7 illustrates the outcome of this question by comparing the responses from both the Owner and EPC organization. As shown in the table when comparing the results, an average of 67% of the respondents indicated that their company had experienced security / firewall problems in the past, but had the problems resolved. They know the security problems and give outsourcers enough rights to get the job done, but not enough to jeopardize critical corporate data. Only a very small percentage (3.7%) of the EPC respondents mentioned that they have decided not to use the collaborative tools.

Table 7: Summary of Company's Difficulties Using Collaborative Tools When Interacting With Other Organizations Due to Security / Firewalls

Response	Owner	EPC
No, our company does not engage in electronic collaborative work with other organizations	6.2%	3.7%
No, we do not have firewalls	0.0%	0.0%
No, we have firewalls and engage in electronic collaborative work, but we have not encountered problems	25.0%	25.9%
Yes, we have experienced such problems in the past and have decided not to use the tools	0.0%	3.7%
Yes, we have experienced such problems in the past, but we can work through them	68.7%	66.6%

The first of the management issues addressed in the survey related to the issue of building a team feeling within a GVET context. A question was asked on how GVET impacts the team feeling for individuals who are geographically isolated from the majority of the group. As illustrated in Figure 22, 73.3% of the Owner respondents and 68% of the EPC respondents specified that GVET members felt less like an integrated team. However, 20% of the Owner respondents and 16% of the EPC respondents indicated that there was no impact due to global virtual teaming and the team members had the same team feeling.

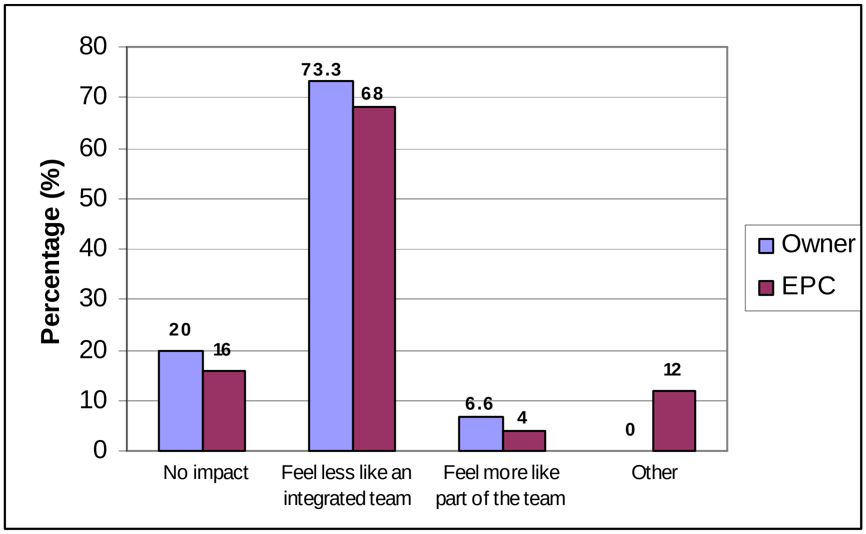


Figure 22: Summary of the Impact of Virtual Teams on Team Building

In global virtual collaborations, building a team environment, developing group norms, and participating in team interaction helped team members to accomplish their assignments (Igbaria and Tan 1998). Continuing the focus on communications and interaction, Figure 23 illustrates the response to the issue of communication comfort. Specifically, the question asked respondents to indicate the impact of global virtual teaming on members voicing opinions on project issues. 73.3% of the Owner and 37% of the EPC respondents mentioned that team members are less communicative in a virtual team.

Nohria and Eccles (1992) assert that although information technology will play a critical role in reshaping the network organization, electronic networks will not replace relationships based on face-to-face interaction. They argue that there exists a certain ratio of face-to-face to electronically mediated exchange required to accomplish meaningful work. Face-to-face communications can be used as an antidote to anxiety, loss of cohesion in the group, help overcome self-doubt, over-sensitivity to an issue, managing under-performance, alienation from other members, restlessness, distrust, dissatisfaction, paranoia, indecision, confusion, toxic, worry, disconnection, mental fatigue, ambiguity, burnout, and social isolation, and can also be helpful in developing sensitivity to diversity of all types (Thompsen 2000).

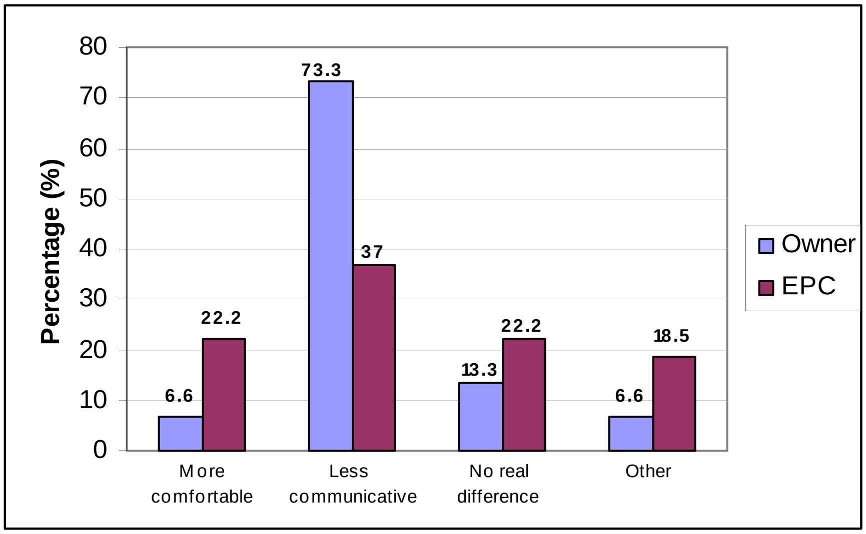


Figure 23: Summary of the Impact of Virtual Teams on Team Member Use of Electronic Communications to Discuss Project Issues

With the introduction of electronic collaboration and distributed teams, managers are faced with the difficulty of communicating with team members who are not collocated in a single office. In response to this issue, managers must adjust their communication options. Figure 24 illustrates the response to the query on how these communications are accounted for by team managers. How do managers in your company compensate for not having the opportunity to sit down with a team member face-to-face to either congratulate or reprimand the team member for his or her efforts? Effective global virtual teams develop a rhythmic temporal pattern of interaction incidents, with the rhythm being defined by regular intensive face-to-face meetings devoted to higher level decision processes, complex messages, and relationship building (Manzevski and Chudoba 2000). As illustrated, direct visits to the distributed team members is a preferred option with a 53.8% and 59.2% response from both Owner and EPC organization respectively. More time on the telephone was also a preferred choice by a majority of the survey respondents.

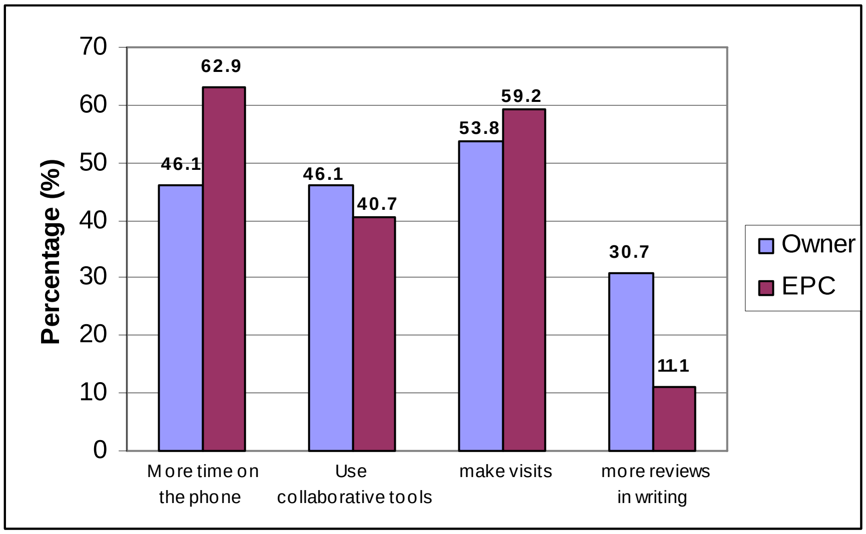


Figure 24: Summary of the Impact of Virtual Teams on Management Response to Distributed Team Members

As indicated from literature on virtual teaming, trust is a critical factor in the successful implementation of GVETs. Geographical dispersion of virtual organizations constrains the ability to develop a shared, reinforced culture of reliability, and the lack of a shared culture inhibits the development of interpersonal trust in virtual organizations (Grabowski 1998). Thus this research included this question on the survey. Figure 25 illustrates the response to the issue of trust in virtual teams. Majority of the respondents felt team members have less trust. Interestingly, 35.7% to 34.6% of the Owner and EPC respondents felt that there was no real difference.

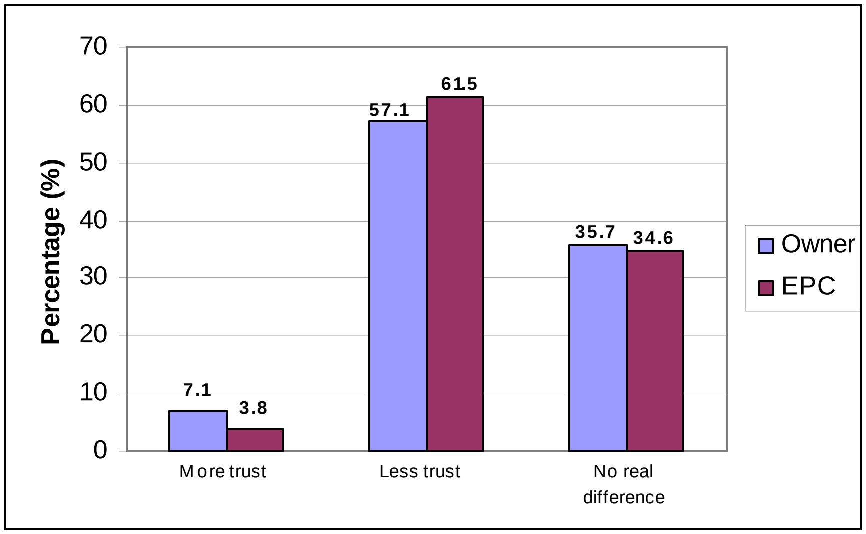


Figure 25: Summary of the Impact of Virtual Teams on Team Trust

In today's global environment, a technical project manager must manage not only the technical requirements of a project, but also the relationships of individuals and organizations from other cultures and nations (Mar-Yohana 2001). Figure 26 shows that 42.8% of owner and 77.7% of EPC respondents mentioned that GVET does increase the time spent by the project management team on the project. And 57.1% of owner and 22.2% of EPC respondents mentioned otherwise.

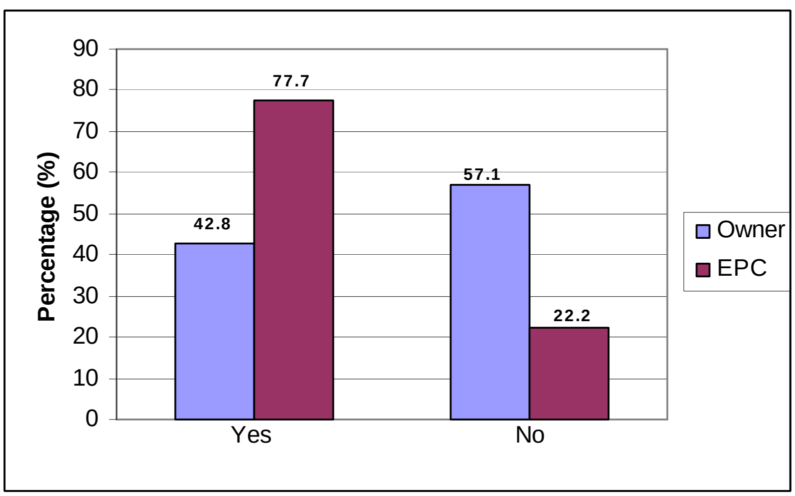


Figure 26: Summary of whether a GVET Increases the Time Spent by the Project Management Team on the Project

Figure 27 shows that 68.7% of owner and 92.5% of EPC organizations plan to increase the implementation of GVET. It was interesting to note that no respondents mentioned decreasing GVET implementation. This clearly confirmed the increasing trend among survey respondents.

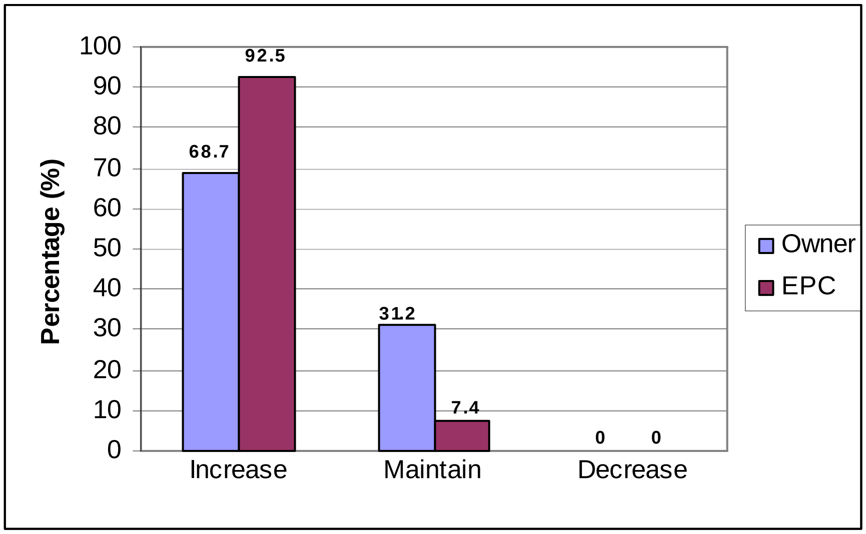


Figure 27: Summary of Company Plan to Increase, Maintain, or Decrease GVET Implementation

4.1.3. Frequency Distribution of Success / Failure Factors

Appendix C shows a detailed outline of the most important factors listed by the survey respondents that lead to successful and unsuccessful GVETs. The results were from 47 respondents; 13 Owner and 20 EPC companies. Several companies had multiple responses from various employees. The majority of both Owner and EPC companies had greater than 5 years experience working with global virtual engineering teams on multiple projects.

The success and failure factors outlined in Appendix C address different perspectives but are rather complementary and share some common elements to that of a good traditional team. Table 8 summarizes the top five success and failure factors from the survey with the number in brackets indicating the frequency of respondents listing the corresponding factor as critical.

Table 8: Summary of the Success / Failure Factors

Owner & EPC	
Success Factors	**Failure Factors**
Clear & frequent communication, periodic face-to-face meetings (16)	Lack of or poor communication, face-to-face meetings (19)
Good communication tools & IT compatibility (15)	Lack of understanding of local work practices, cultural differences, and/or language issues (14)
Standard work processes and communication procedures (11)	Lack of management involvement & experienced leadership (9)
Clearly defined scope & expectations (10)	Changes (goal, scope), slow response to change (8)
Clearly defined roles & responsibilities (9)	Incompatible or poor technology including, hardware and software (7)

Differences in work ethics or with local work practices are a failure factor. Work ethics are the generally accepted practices within a culture's work and business environment. This includes the proper time to attend meetings, regular working hours, the value placed in strong effort as opposed to efficiency, the value of teamwork, and the general association that people hold with their peers within an organization (Mar-Yohana 2001).

The trend toward physically dispersed work groups has necessitated a fresh inquiry into the role and nature of team leadership in virtual settings (Kayworth and Leidner 2002). As mentioned in Table 8, lack of management involvement and experienced leadership is a very common factor for failure. Effective team leaders demonstrate the capability to deal with paradox and contradiction by performing multiple leadership roles simultaneously (behavioral complexity); they act in a mentoring role and exhibit a high degree of understanding (empathy) toward other team members; at the same time they are able to assert their authority without being perceived as overbearing or inflexible; and finally they are extremely effective at providing regular, detailed, and prompt communication with their peers and in articulating role relationships (responsibilities) among the virtual team members (Kayworth and Leidner 2002).

Some of the other common failure factors during GVET implementation include language issues and local culture of the overseas office. Some of the noticeable cultural traits of foreign office could be the following. Team members in support office can be shy, soft spoken, reserved and low voice. They could be polite, humble and may have a high amount of respect for elders. The work style in the support office could be in such a way that the superior makes decisions; subordinate carries them out. The overseas office team members might also hesitate to disagree and contradict others. Other cultural traits may also include eye contact with female colleagues is low and public display of emotions / affections are discouraged. Some of the language issues could be due to the use of different words that has the same meaning, but are used differently depending on the country of origin. When comparing with Asian Indian vs. American English there are some interesting usage patterns, e.g., ‘phone is engaged’ means ‘phone is busy’, ‘lift’ means ‘elevator’, ‘repair’ means ‘fix’, and ‘fix’ means ’assemble’.

4.2. Further Observations from Survey Data

Within the responses received from EPC, 83.3% of the companies that had greater than five years GVET experience were working on large sized projects worth more than US$100 million. Also 83.3% of the EPC respondents that had indicated ‘no’ increase in the time spent by the project management team were companies that had greater than five years of experience and also working on projects sizes of more than US$100 million. This shows that more the experience with GVET by a company less the impact on their project management time. Another observation was that 83.3% of the companies with greater than 5 years of GVET experience said that their top driver for GVET utilization was driven by the need to reduce engineering service cost. 54.5% of the companies that had their top driver as engineering cost reduction were working on US$100 million size projects or more. Also 27.2% of the US$20-100 million size projects had their top driver as engineering cost reduction.

Now from the responses received from owner, 60% of the companies that had greater than five years GVET experience were working on large sized projects worth more than US$100 million. Also 50% and 62.5% of the owner respondents that had indicated 'no' to increases in the time spent by the project management team were companies that had greater than five years of experience and also were working on project sizes of more than US$100 million respectively. This shows that the more experience a company gains with GVET, the less impact it has on their project management time. Another observation was that 60% of the companies with greater than 5 years of GVET experience said that their top driver for GVET utilization was driven by the need to reduce engineering service cost. 55.5% of the companies that had their top driver as engineering cost reduction were working on US$100 million or more projects.

4.3. Interview Results

After analyzing the survey results, follow-up interviews were performed with 21 participants. This section focuses on the industry executives' suggestions of success factors and recommended practices on how to establish or optimize the corporate and project infrastructure required for GVET implementation in the areas of organization, communication, quality, technology, scope definition and work share, and project control. The following description was developed after a detailed content analysis of all interviews.

To provide further clarification of the contents in Appendix D and also with this section the following types of offices are described. A lead office is a home country-based headquarter or branch office who directly serves customers and may also perform engineering tasks on a project. Support offices are those subsidiaries, affiliates, alliance partners, or subcontractors who perform engineering services on the project and report to the lead office.

4.3.1. Organization

With regards to the organization category for GVET implementation, the following items were identified as important for success:

- identifying and employing staff with desired skills such as multilingual skills, cultural experience or culture sensitive;
- experience with company / lead office work practices;
- flexibility to new ideas, methods, processes, and work outside normal working hours;
- experience with codes and standards in different countries; and
- nationality

Interpersonal skills for appropriately communicating with other team members are also critical. If there is difference of languages between lead and support offices, capable interpreters will play an important role and may be especially critical to success in cross-cultural negotiations. While sending expatriates to the lead office, providing mentors for them is beneficial. Administrative matters regarding passport, citizenship requirements, residency status, visas, and work permit issues that involve time limits need to be addressed early and cannot be neglected once there is cross-border mobility of GVET members between offices.

The company should provide specific training on codes and laws in countries of operation, global team management skill training, information technology training, standard design application training, language and communication skills training, cultural awareness training, standard work processes training for GVET employees and must ensure that the client's business philosophies, specifics, norms, and practices are clearly understood. Also, language and cultural training can be provided to family members. Systems such as rewards or recognition have to be developed to motivate engineers in all offices with GVET capability. The incentive and recognition practices of the support office(s) must be recognized and respected. The appropriate contract structures or management techniques within structure must be defined. In addition to all the above mentioned critical aspects of organization, it is also important to establish a company culture emphasizing safety.

4.3.2. Communication

Open, clear, consistent, prompt, frequent, and transparent communication within and among all offices must be ensured at all times. Language barriers can result in comprehension and intent errors, and must be effectively managed. Recommended measures include hiring multilingual employees and interpreters to facilitate communication when possible; developing technical dictionaries that translate between technical terminologies; and establishing information confirmation mechanisms, for example, asking people to repeat important information to the communicator for confirmation.

It is a good practice to document and distribute office work processes and procedures to engineers and make sure they clearly understand these processes. Knowledge management systems have increasingly been accepted by leading companies to capture and disseminate project and location knowledge between company offices. Most common forms of knowledge management systems include a lessons learned database.

Building team camaraderie and trust between lead and support office engineers are crucial for successful GVET application. These can be enhanced through personal, face-to-face interaction and travel to other locations. To exploit the expertise of experienced GVET personnel between offices, it is an effective strategy to rotate personnel. Conducting periodic meetings are very important for facilitating communication. Meetings can include holding frequent conference calls between the lead and support offices; weekly or periodic project review meetings between lead and support office managers; mandatory discipline meetings at a regular interval; periodic face-to-face project meetings between group leaders; and face-to-face meetings at key points of time in the project lifecycle.

4.3.3. Quality

Ensure accurate communication of requirements of client, government, and other project participants to all office locations. Develop and enforce a comprehensive engineering quality assurance plan. Quality awareness among all team members needs to be established upfront. It must be ensured that all team members understand the required quality expectation and have needed code and standard references, and each office should tailor training to meet the engineering process requirements. It is also critical to make sure that proper quality control reviews are performed.

4.3.4. Technology

To support collaborative team work, information technology applications should be standardized among involved offices. Recommended practices include: coordinating accounting system and earned value measurement system integration; ensuring IT infrastructure is in place before projects begin; ensuring high speed internet and secure communication links are set up; acquiring collaborative design tools when appropriate; and ensuring standard approaches in applications, e.g., use standard level structure for CAD, font page setup for word processing, etc. Use appropriate technologies for communication. Appropriate communication tools may include a video conferencing system and web-based collaborative tools to support the transmission of presentations and whiteboards (e.g., Microsoft Net Meeting). The work force must be trained in appropriate information technology solutions. Only when the selected information technologies are well commanded by employees, can they function as expected. Training content includes electronic data management systems, CAD execution plans, and engineering software and licensing. It is also recommended to standardize hardware when possible to minimize conflicting hardware issues.

4.3.5. Scope Definition and Work Sharing

In this section the first items that were identified by the executives are to define project requirements (performance metrics and expectations) and to identify the goals of all potential partners. It is important to obtain the client's support or buy-in to the GVET strategy. Some of the things that need to be considered during the investigation of potential geographic locations or teaming partners for work performance are to identify core competencies of potential engineering location, their experience, good language skills, local laws that have to be strictly followed, and local employment laws and regulations. The work sharing for the project must be clearly defined and aligned with the project goals. Team members must have the same project objectives. A clear, written, well defined scope of work responsibilities for each location is necessary. Work sharing must comply with legal requirements. Local content requirements need to be defined. Work sharing must consider trade policy limitations and implications. Ensure no restrictions on the transfer of technology across borders. Work sharing must consider any security requirements regarding files, work area, any export compliance issues, Defense Contract Auditing Agency (DCAA), or Federal Acquisition Regulation (FAR) requirements, and intellectual property protection. Roles and responsibilities of all office locations should be clearly defined. For example, who is responsible for each task, key contacts for the tasks, rules and practices, engineering work processes and procedures. A methodology for issue resolution must also be described. Another critical item to this section is the identification of key transfer points and then managing the deliverables at those hand-off points.

4.3.6. Project Control

Integrate accounting systems as needed to receive accurate reporting of engineering costs. Detailed cost reviews must be performed on a periodic basis, for example accounting for the travel, living, and other potential expenses for expatriate or rotating engineers. Integrate engineering schedule in lead and support offices to meet client's requirements. Take holidays in different locations into account when scheduling. This can be a considerable schedule issue for different country environments.

4.3.7. GVET Issue Examples from Interviews

This section documents several interesting examples of challenges and issues that can be encountered when using GVETs. They are quotes taken from interviews. The names are withheld due to confidentiality reasons.

> <u>Commercial alignment</u>
>
> "On the same project when one of our engineering companies worked on a reimbursable basis and another one worked on a lump sum basis, they tended to approach the job differently. This gives rise to different drivers there for success for each of those companies and there can be little conflict. The guy whose on lump sum is forever telling us no, I am not going to do that, it is going to cost more money and the other guy is saying, well anything you want, sure we will do it."
>
> <u>Basic measurement setup</u>
>
> "We did a common 3D model between two countries and when merging it did not fit. The basic measurement setup for each of the projects was just wrong. Everyone did the standard stuff of each other offices."

<u>Video conference</u>

"When video conferencing, there was a time lag between asking a question and the question appearing at the other end. For example, you have a 3 second round trip delay between asking a question and having even your question come back to you from the other end. That's a long silence to tolerate. The conference fell apart because you ask the question again and by that time they get the question and are trying to answer you back. The whole thing was a waste of time."

<u>Redesign (cultural)</u>

"Some people kept saying well, here is how we design in the west. And every time they turned their back the local designers said well they are crazy, we don't do it that way. So the building would shrink whenever the westerner showed up and then expand again when they went home."

<u>Language</u>

"Some words in another language did not translate to the same word in English. For example, when they said ignore this, in French what he was trying to say is that he was not aware of it. But it was coming back over the phone line as I am ignoring this, I don't really care."

<u>Cultural gap (communication gap)</u>

"The engineering company was saying that we would like to get this approved as the materials to use. Can we do this? And the answer came back as yes. But what should have come back was 'yes, but you would be crazy to try because it is going to take you three years. In the email you think you are getting the whole story, but you are not getting the nuances that come with it."

<u>Seamless deliverable</u>

"The client was talking to one of our senior Vice Presidents and said that I didn't realize that you had an office in this country, why didn't you bring them

> into the picture and have some of the work executed there. And of course our senior VP said we did."

4.3.8. International Interview Findings

This section summarizes some of the support office managers' viewpoints with GVET utilization. The following information is based on the data obtained from the interviews with 4 international managers.

Both the international managers and home office managers had the same opinion on the following:

- Face-to-face meetings and early involvement of all the key players;
- Common objectives, commitment, clear roles & responsibilities, rules and practices; and
- Well established standard tools and good system that has working compatibility in terms of software, hardware, electronic communication / data transfer;

Team research and goal setting theory has demonstrated the importance of establishing a common purpose among team members and then working towards this purpose to increase team effectiveness (Hacker 2000). Some of the drivers identified by the international managers were to gain large supply of younger engineers, gain work overseas, and make projects economically viable.

Knowledge Management Systems

The main drivers for implementing KM initiatives are (Robinson et al. 2001):
The dissemination of best practice to a key set of employees; the retention of the tacit knowledge of key employees; to promote continuous improvement; the need to respond to customers more quickly; and the need to reduce rework. The support office managers also agreed to acknowledge the fact that establishing Knowledge Management Systems aids in more effective GVET implementation.

Annual evaluation / motivation / recognition / rewards / incentives

The international managers agreed that these practices have definitely helped to motivate GVET members. Some of the recommendations included developing project incentive programs. Celebrate when key project goals are achieved. Develop some incentives that are tied to overall project performance, not just performance from one part of the team. Also, send visiting executives from the lead office to a support office to boost morale through individual or group discussions with employees. It is important to understand the items that people value and also it is better to leave detailed decisions regarding appropriate rewards and recognition to the local office management.

Cultural differences, cross-culture communication

Cultural issues and poor leadership lead to misunderstandings and conflict that are not easily resolved. Cultural differences must be acknowledged and careful selection of the project manager was recommended.

Experience

The international managers mentioned that with more experience with GVET implementation, they have figured out ways to overcome the challenges and have improved drastically on their project performance metrics such as engineering cost, construction cost, engineering time, overall project delivery time, engineering quality, and construction quality.

4.4. Summary

The results described in this chapter clearly indicate that GVET use on projects within the EPC Industry is on the rise. The most frequently used tools for administering GVETs are e-mail, common repositories for project information, video-conferencing, and project specific websites. Almost 50% of the total Owner and EPC respondents indicated that there was a more than 10% reduction in the engineering cost with GVET utilization. The top three driving factors for GVET implementation are the need to reduce engineering service cost, driven by competitors, and driven by global customers or local customers. The most important success factor was clear and frequent communication and periodic face-to-face communication. Making face-to-face visits to the distributed team members and also more teleconferencing are still the preferred option. Even though the word ‘virtual’ is found in GVET, some element of face-to-face interaction is critical and cannot be avoided. And finally one of the most critical failure factors was a lack of understanding of local work practices, cultural differences, and language issues.

CHAPTER 5

CASE STUDY PROJECT

A detailed case study example was very important to this research. This helped to understand and get a better idea of some of the real project experiences faced by a CII Company while employing a GVET strategy. To obtain the information for the case study, face-to-face interviews with two company executives were performed.

The interview questions asked followed a similar pattern to those contained in Appendix E. After the interviews, a detailed content analysis was performed to produce the following explanation of the case study.

5.1. Strategic Evolution of Engineering Services Utilization: Introduction

In this epoch of globalization, Owner-Operator companies are searching for more effective strategies in acquiring engineering services. Stiff competition and the need to reduce engineering service costs for capital projects are a major concern for these global companies. One strategy that these major companies are increasingly considering is to reduce the cost of capital projects through global competitively sourced engineering services. The two primary approaches are by direct contracting with an off-shore engineering company or by contracting with a major US-based engineering firm with connections to an off-shore engineering firm (through an alliance, partial ownership or some other contractual arrangement). Advancements in communication and information technology make it possible for project team members to work together as a team irrespective of whether they are collocated or not. But by engaging global engineering companies for engineering design services, many challenges must be faced, both managerially and technologically. Global engineering distributed teams have many cultural, economic, political, and technological aspects that must be evaluated and addressed in order to successfully execute capital projects.

In the early nineties, a CII member company (referred to through this case study as "the Company" was looking at various strategic options to reduce the cost of engineering design on capital projects. Due to increasing competition, the Company was facing pressure to reduce costs associated with capital project execution. The Company's engineering leadership began looking at global competitively sourced engineering services (GCSES) as a strategic option.

5.2. GCSES: Getting Started

The Company's objective for a series of large expansion projects was to reduce the total cost of engineering design and procurement services through global competitively sourced engineering services (GCSES). The capital projects were to be located in Europe and the U.S. It was the Company's first major venture into doing detailed engineering offshore. The reinvestment program started in the early nineteen nineties and involved 3 projects, each costing approximately US$100 million; 2 projects were located in the U.S. and 1 in Europe. They were complex, high hazard type processes with completely new technology as the heart of the process. The first project which was in the U.S. used a scaled quarter inch to a foot "stick" model. Today's standard 3D CAD design tools weren't quite ready for full scale production design. The second project was located in Europe and the third project was located in the U.S.

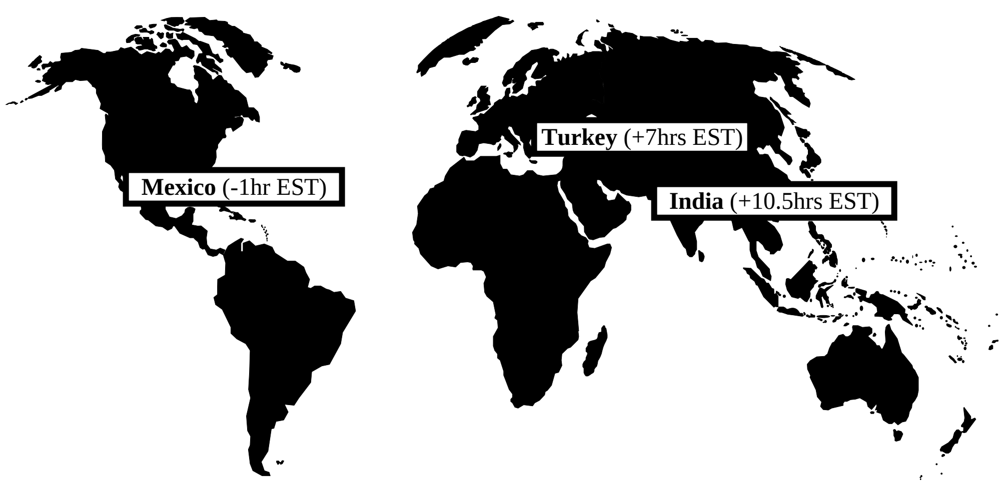


Figure 28: Case Study Project Locations

The Company considered engineering contractors in Mexico, India and Turkey because they had prior project experience in these respective countries.

– Experience in Turkey: was a joint venture plant located in Turkey designed and built in collaboration with a Turkish engineering contractor. It was a US$60 million project. The Company was impressed with their capabilities.
– Experience in Mexico: The Company had previous experience with an engineering contractor in Mexico for design of minor projects for an in-country operating plant.
– Experience in India: The Company also had prior experience with an Indian contractor who worked on the same Turkey project as referenced above.

During the evaluation and selection stage for a contractor, the Company also took into consideration other well known engineering companies in India. But finally the Company selected the same contractor in India as referenced above on the basis of favorable experience with them on the Turkey offshore project, more cost effective rates, and better communication skills with the English language versus the other contractor options.

The Project Manager explained that, "if we hadn't had prior experience with the Indian contractor, there were other criteria that would have helped us in the selection process: We would look at the major players and would interview them. We would look at not only cost, but also their track record, their history of working with multinational companies, their values, and their safety. We would talk with reference companies to see how satisfied they have been with their working relationship. We would also look at their technologies; how advanced they were in terms of their CAD design capabilities, how compatible they are with our systems, our philosophies, and our way of doing things."

5.3. Success Strategies

One of the strategies enforced by the Company on the first two projects was the GCSES functional leads participation in the Front-End-Loading (FEL) process. The participation duration was approximately 3 to 4 months each. The Company follows 3 FEL processes:

- FEL 1: Business Planning Process
- FEL 2: Facilities Planning Process
- FEL 3: Project Planning Process

FEL 1: Business Planning Process

The 'Business' looks at various options and then narrows down to the best viable option based on a variety of critical selection criteria. Then some high spot estimating and financial/return on investment calculations are performed. This process is basically led by the 'Business' with minimum engineering involvement.

FEL 2: Facilities Planning Process

Engineering gets more involved from here. This phase looks at and defines the design basis for the total facility and performs a more definitive estimate. The Project Manager added, "We do some screening reviews known as gate-keeping reviews. We review with the 'Business' and our management at the end of each of the FEL processes. If it's still a viable project, then it proceeds to FEL 3 or else we would stop right there and not proceed any further."

FEL 3: Project Planning Process

The project manager noted, "Here is where we do the Basic Engineering activities, which includes preliminary P&IDs, flow sheets, single line diagram, develop detailed equipment list, vendor selection, quotations for equipment, etc. At the end of this process, 25-30% of the engineering for the total project is complete. This gives enough information to put together a good quality estimate for the total project. The estimate is used to obtain full funds authorization; authorizers are determined by the size of the capital investment per Company protocol. During this process, the offshore project managers, lead engineers are brought into the home engineering office; not all at the same time but depending upon different stages of FEL 3. This leads to a clear understanding of goals, objectives, and requirements of the project. Typically, for projects with a US-based full service engineering contractor, a 'production design basis package' is put together by the owner and provided to them to do the detailed engineering. For projects with an offshore engineering company, the leads from the offshore office visit the home engineering office and together a 'production design basis package' is developed. At the end of FEL 3 on the first project, the offshore leads went back to India. The leads from the offshore office were deeply involved in putting the package together so that they understand what is in there. The main office helps them in the process of putting it together. A smooth transition was achieved. They do work, learn the project and take back the knowledge to the offshore office to transfer to the respective discipline teams members."

The Company had assigned a Resident Project Manager at the contractor's office for the duration of first two projects (3.5 years). There were long-term visits of about 3-4 months at a time by craft specialists from U.S. and Europe during peak of production design. The areas that needed this kind of owner engineering support were in the Piping and Electrical / Instrumentation type arenas. There were also short-term visits by key owner project team members for model design reviews.

5.4. Production Design Process

The Company set up a restricted access area within the GCSES contractor's office. Due to proprietary technology, a separate area for visitors was also established. The General area was a separate area for anybody, any vendor coming, any visitor coming.

It also had a separate conference room set up for visitors that could come in and discuss the project with engineering personnel. The company set up E-Mail and A-2 size fax machines at both ends for communication and vendor data transmittal. Weekly telephone communications by discipline was mandatory. Document transfer via courier service took 3-4 days from the U.S., and 2-3 days from Europe. Today, everything is electronic.

5.5. Offshore Engineering Office Performance

The first project design quality was fair. The project manager explained, "We brought all the material from the U.S. to India to build the model. They did a great job but again since this was their first time, we helped them put together the scaled stick model. Typically when we do scaled stick models, our experienced designers skip the whole process of doing piping arrangement drawings. They are so good at it that they take the measurements directly from the model and create isometrics using the dimensions from the model. But the offshore engineers lacked this sort of experience and they weren't familiar in developing isometrics directly from the scaled stick model. This was one mistake that we made and that was a learning for the owner's engineering leaders."

The second and third projects design quality was good. It did not involve a stick model. The pipe isometrics were developed directly from piping arrangement drawings. But the offshore contractor needed guidance on Civil / Structural / Architectural design due to a lack of U.S. and European design experience. They had more experience on concrete vs. steel design. This was another learning process for the home office. The contractor was very strong in the Electrical and Instrumentation functions. The design quality met or exceeded expectations.

Two additional major capital projects followed the initial three, with the fourth project authorized in 1996 and the fifth project authorized in 2001. For the fourth project (Europe), the design quality was very good. The same offshore contractor was used. But this time there was no resident project manager in the GCSES contractor's office. The fifth project was executed using a US-based full service design contractor who sub-contracted a large portion of the design to a subsidiary company in India (different Indian engineering firm than the Company used in the first four projects). Once again, the quality of the design from the GCSES Company was very good. The average engineering costs for the five major expansion projects was 10.2% versus the Company's average of 16.9%.

5.6. Project Experience Summary

"The Company" has successfully executed projects using global competitively sourced engineering services (GCSES) and has achieved significant savings in doing so. The Company has worked either directly with the GCSES Company or worked through a full service design contractor in U.S. and Europe who subcontracted work to a partner company in India. In all cases, the overseas office was very proficient in the use of the latest engineering and design tools, including 3-D CAD. They used the same tools that the Company uses which was a large advantage from a design compatibility standpoint. They have many people trained in using these tools. The current communication tools make the process totally transparent to the Company's operations personnel. The model is updated every day and transmitted overnight.

5.7. Current Status

Today, the Company is working directly with an Indian company on a major expansion project in the U.S. Again the same process was followed. The lead engineers from India participated in the FEL process. A direct high-speed communication link was established. The Company is also looking for opportunities to leverage the use of this and other GCSES contractors on other major capital projects. The Company is working on developing a work process for executing smaller projects (<$10 million) using some GCSES component for the design. There is some cost associated with setting up an office from scratch; for example computer links, high speed links, travel back and forth, etc. Therefore for smaller projects, it's difficult to offset the upfront costs with the savings that you may make. The manager remarked, "Since we have been successful, we are working with our full service design contractors in U.S. and Europe to develop a work process involving globally competitive engineering companies, not necessarily the same companies that we are doing work with but they should be able to develop a similar kind of setup on their own with companies in other parts of the world. We are having some level of success now."

5.8. Keys to Success

The focus was on a long-term relationship. Significant savings may not be realized immediately due to costs associated with office set-up and training. The project manager explained, "There are some upfront costs that you have to accept. Business Leadership must be fully aligned and supportive. Businesses must be able to overlook some short-term setbacks for long-term gains. Leadership must drive teamwork to achieve positive results. We had full and total support from our businesses. There are always some risks associated. But now since we had performed it successfully, we have less of a problem selling it."

The training of personnel is critical. Lead engineers and designers from offshore engineering company must understand the technology and the owner Company's project system. This will require them to work side-by-side with U.S. folks for a period of time to understand the technologies, work practices and the value systems. The main office functional lead engineers and designers must also learn to work with people from a different culture. Some level of direct interaction with the offshore company will be required from time-to-time.

5.9. Issues to Consider

Even though the strategy to reduce the cost on capital projects through a GCSES contractor was successful, there were several other aspects that required careful consideration. Some of them were as follows: high cost of expatriates and long-term visitors; high cost of travel to India; extra electronic communication setting up cost; high speed internet lines; and almost 10 hours time difference between Eastern U.S. and India. But this may work as an advantage since the Indian office is working while U.S. office is sleeping, a 24 hour design cycle can be developed. On a schedule driven project, this actually works to the company's advantage. Other issues that needed consideration were a lack of total team commitment to this approach and verbal communications challenges. The team must always check for the same understanding.

Negative reactions

The Company had experienced some negative reactions while adopting this GCSES strategy. This issue was very critical and had to be addressed upfront. The Company was clear in explaining within the organization that this allows them to stay competitive on a global basis. The manager remarked, "This strategy helps us put in more competitive facilities right in our backyard so that our economy can grow and move forward, rather than putting them somewhere else."

Motivation

During the implementation of projects by using GCSES, the company had identified some of the key items for motivation. The items were as follows: Face-to-face interaction was very important, every 3-4 months overseas office visit by managers' helps to motivate the work force in that office, the offshore office needs to feel that they are an integral part of the team, taking out the whole team for dinner is another good idea. The Company didn't interfere with the offshore offices' rewards or incentive structure or recognition system. But instead, the company made it a point to make recommendations and acknowledge any members job well done.

5.10. Case Study Summary

The Company has successfully delivered major, complex projects through global competitively sourced engineering services for over 12 years. Offshore companies have always met their cost and schedule commitments. A quality product is obtainable with proper training, guidance, and a thorough understanding of expectations. Work processes must be set up for success. Business Leadership Commitment and Support is the key to success, that is, the process must be driven from the top. The entire project team must be fully aligned and committed to making it a success. But this will require some personal sacrifices (e.g., overseas travel, early morning phone calls) to make it happen.

This is just the beginning of doing business in a global economy. The company's engineering leadership still faces other tough challenges and major risks that has become a part and parcel of the ever growing global engineering services sector. Due to the dynamic nature of the current business practices in an era of globalization and the technological advancements, proposing a strategy for expanding the company's GCSES policy to other foreign locations is a difficult undertaking, but the cost advantages and resulting more competitive facilities are worth the extra engineering effort.

Corporations are forced to go offshore when their competitors take advantage of these huge wage disparities. Despite the added costs and risks associated with going offshore, corporations have discovered that they can reduce their costs of engineering by as much as 45%. By reengineering the process, firms can now save up to 70% of initial engineering costs. While wages in countries such as China and India may eventually rise as their living standards improve, the sheer size of their populations and their far lower costs of living mean that their low wages will put pressure on the U.S. work force for a very long time to come. When and if their wages reach those in the United States, a new wave of emerging nations may replace current nations providing low wage labor (Lieberman 2004).

CHAPTER 6

CONCLUSIONS

To remain competitive, companies that perform engineering work in the Engineering, Procurement, and Construction (EPC) Industry are increasing the use of globally distributed teams for engineering services. This chapter presents a summary of the primary research findings and their contribution to the EPC Industry. A discussion of limitations of this research is also presented. The chapter concludes with possible future research and concluding remarks.

6.1. Research Summary

The global sourcing of engineering services in the EPC Industry has become an increasing trend in business. The primary goal of this research was to perform an exploratory investigation into the use of Global Virtual Engineering Team (GVET) in the EPC Industry. A Global Virtual Engineering Team (GVET) is a group of geographically dispersed individuals organized through communication and information technologies that need to overcome space, time, functional, organizational, national, and cultural barriers for the completion of a specific engineering task. The EPC Industry faces many challenges when utilizing GVETs on capital projects including:

- How do you transfer your tools, work processes, and technologies in multiple offices?
- What technologies and management structure is required to effectively execute engineering design services with a GVET?
- Are there regional/government requirements (regulatory) and what are they?
- How do you manage cultural differences between locations?
- How do you develop a team building process, training, and morale building in the virtual team environment?

- How do you protect intellectual property and satisfy licensing requirements?

To achieve the goal of this study, a survey was developed and data was collected from 46 respondents from large owners and EPC contractors. The top three forces driving companies toward the use of global virtual teams to provide engineering services identified from this research are 1) driven by the need to reduce engineering service cost, 2) driven by competitors, and 3) driven by global customers or local customers. Corporations are very actively investing the setting up development centers in countries with low cost, well-educated labor, such as India, Russia, China, the Philippines and Eastern Europe. The current status of GVET utilization within the EPC Industry was analyzed with 58% of the Owner respondents and 67% of the EPC respondents indicating that they use GVET on many projects. Also, 47% of the Owner respondents and 56% of the EPC respondents pointed out that they use GVETs on projects that are more than US$100 million in size.

This research also confirmed the perception of many who state that GVET implementation will continue to increase with 69% of Owner respondents and 93% of EPC respondents supporting the increasing trend and only 31% of the Owner respondents and 7% of the EPC respondents stating that they would maintain their present level of GVET utilization. None of the respondents were of the opinion that they would decrease GVET implementation on their projects.

The objectives were also fulfilled through a case study of a large company which performed five projects through the use of global virtual engineering teams. In addition, detailed interviews with 21 executives from the EPC Industry were performed. The case study and interviews aided in understand criteria for successful GVET implementation, implementation challenges, current status, and future trends.

Best practices were identified through the survey and further defined through the detailed interviews. Best practices for GVET implementation were 1) clear and frequent communication; 2) periodic face-to-face meetings; 3) good communication tools and IT compatibility; 4) well defined standard work processes and communication procedures; and 5) clearly defined scope, expectations, roles, and responsibilities.

6.2. Contributions

This study contributes to the existing knowledge in virtual teaming and globalization within the EPC Industry in several ways. First, data was collected to document and gain a better understanding of the current status of GVET utilization in the EPC Industry. At this time, there are not many quantitative studies being performed to understand GVET in the EPC Industry and more data is needed to improve our understanding of this increasing business practice. This research identified and quantitatively ranked the driving forces of the companies studied, and also defined work tools and management techniques that they use when implementing a GVET strategy.

Another contribution of this research is the identification of perceived implementation factors that impact success of a GVET through the survey, case study analysis, and interviews with executives within the EPC Industry. These success factors were documented along with examples from the interviews and case study.

6.3. Limitations

The majority of the data collection for this research focused on companies in the Construction Industry Institute (CII). Most of the participating companies were already implementing GVET for their capital projects. A certain amount of bias may be found within the data collection with regards to GVETs advantages based on the perception that they may be defending previous decisions to implement GVET on projects. Therefore, it is not appropriate to assume that all companies within the EPC Industry support this trend of GVET implementation for their projects.

Most of the interviews were conducted with owners and contractors from the United States. At this stage, interviews with a significant number of foreign experts were not performed although a small number of (four) international managers were interviewed. The research is therefore limited by the international perspective and managers from international offices may have other valuable additions to the success and failure factors.

Various best practices and critical success factors were identified in this research. Since this is a broad, exploratory study, a detailed analysis of each of these factors was not performed for this research.

6.4. Future Research

There are many opportunities for future researchers to make a contribution to the effective use of GVETs in the EPC Industry. One potential study could aim to develop a checklist of preliminary (threshold) conditions for companies to adopt/optimize global engineering strategies. Create guidelines to define the minimum functionality of collaborative technologies. Develop a framework for global engineering work force establishment and maintenance.

Another important study could be the identification of more specific criteria that practitioners use to measure their global engineering team performance. If team performance is defined, then a more quantitative analysis of criteria that define effective global virtual teams could be developed with an assessment of team features and their impact on performance.

This research was primarily performed with data from a US company perspective. Further research should be performed to develop a more thorough and comprehensive understanding of the perspective of other managers and engineers in other countries and cultures. Each country has their own conditions which will impact the application of GVETs.

Similar research could focus on companies within the Architecture, Engineering, and Construction (AEC) Industry (instead of the EPC Industry focus in this study). The primary focus of companies within the AEC Industry is the development and construction of buildings. While virtual teams have been used in this industry for some time, particularly for architectural and engineering design services, the ability to perform these services at a lower cost with architectural designers and engineers from lower income country may significantly shift the team makeup in the future. Building projects tend to be smaller in scale and more diverse in engineering service requirements, so to date, there has not been large scale adoption of virtual teaming strategies in the AEC Industry for cost efficiency reasons. This could change in the future and further analysis of the challenges that may be faced by the industry companies would be valuable.

6.5. Concluding Remarks

The results of this study are expected to help Owners, EPC Organizations, and international engineering offices during their utilization of global engineering teams. This will not only guide the inexperienced company's through their decision-making stages but can also assist experienced firms by helping them avoid overlooking crucial success factors. The results from this study are also being used as a starting point for the development of a global virtual engineering framework by the Construction Industry Institute Project Team 211. The research team's goal is to develop these results into a framework that can be implemented by managers early in a project so that they can more effectively plan their teams for success. The results can also aid academia to better prepare students for working effectively in globally distributed teams.

The goal was to provide the reader with the current trend of GVETs in the EPC Industry with supporting facts and figures. There are many challenges that companies face when using GVETs. This research was aimed to identify these challenges and document methods that companies are using to address them.

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APPENDIX A

Owner Organization Online Survey Instrument

Effective Use of the Global Engineering Work Force Survey

Construction Industry Institute

Construction Industry Institute (CII) PENNSTATE

CII PROJECT TEAM 211

The Pennsylvania State University

With advancements in technology and the globalization of economies, Virtual Teams (VT) have become a reality in the global engineering sector. The Construction Industry Institute in collaboration with Penn State University is investigating the effective use of the global engineering work force. Our research team's goal is to develop a framework to address the comprehensive issues involved in establishing successful global virtual engineering teams through the identification of best practices in the utilization of personnel, work processes, tools and technologies. For additional information, please go to the Project Description.

A *Global Virtual Team* is a group of geographically dispersed individuals organized through communication and information technologies that need to overcome space, time, functional, organizational, national, and cultural barriers for the completion of a specific task. For the purpose of this survey, please only consider Global Virtual Teams that contain members located in at least two countries.

We request your assistance with this study by completing an online survey. Please proceed to the appropriate survey by selecting either the Owner/Operator or EPC Organization survey below.

Go to Owner / Operator Survey

Go to EPC Organization Survey

As the research progresses, we will update you with the latest results. All information will be kept strictly confidential. Thank you for your cooperation. Please contact me if you have any questions or comments.

Sincerely,

John I. Messner, Ph.D.
Assistant Professor of Architectural Engineering
The Pennsylvania State University
104 Engineering Unit A,
University Park, PA 16802
Tel: 814-865-4578
jmessner@engr.psu.edu

Effective Use of Global Engineering Work Force Survey

FOR OWNER/OPERATOR

Construction Industry Institute (CII)
CII PROJECT TEAM 211
The Pennsylvania State University

This survey form is for OWNERS / OPERATORS.
If you work for an EPC Organization, please go to this link: EPC Organization Survey
For the purpose of this survey, please only consider Global Virtual Teams that contain members located in at least two countries.

All information will be kept strictly confidential. By submitting this survey, you are consenting to participate in this research project. Further information regarding this consent can be found at: http://www.arche.psu.edu/faculty/JMessner/otherpages/consent.pdf

SECTION I: BACKGROUND INFORMATION

Your Name:

Company Name:

Position/Title:

Telephone:

E-mail:

1. How many years of experience do you (personally) have with global virtual engineering teams (may be with different organizations/companies)?

- ☐ None
- ☐ < 1 year
- ☐ 1 to 5 years
- ☐ > 5 years

2. How many years of experience does your company have with global virtual engineering teams?

- ☐ None
- ☐ < 1 year
- ☐ 1 to 5 years
- ☐ > 5 years

3. What size projects (in total installed cost) has your company executed with global engineering teams? (check all that apply)

- ☐ Up to US$ 5 million
- ☐ US$ 5-20 million
- ☐ US$ 20-100 million
- ☐ More than US$ 100 million

4. During the engineering process for capital projects, how frequently does your company use global virtual teaming (VT)?

- ☐ We use global VT as an integral part of all projects
- ☐ We use global VT on many projects
- ☐ We are experimenting with global VT on our first project(s)
- ☐ We are not using global VT

5. If your company has used or is experimenting with global virtual teaming, what is the purpose for using the teams (check all that apply)?

- ☐ Communication inside our Organization
- ☐ Communication with Engineering/Construction Organizations

6. What are the drivers for making decisions in improving the distribution of engineering work among the global engineering work force? (1 = least important & 5 = most important)

	1	2	3	4	5
Driven by the need to reduce engineering service cost	○	○	○	○	○
Driven by the need to reduce the engineering schedule	○	○	○	○	○
Driven by the need to improve engineering quality	○	○	○	○	○
Driven by the need to locate services close to the project location	○	○	○	○	○
Driven by global customers or local customers	○	○	○	○	○
Driven by the need to understand/comply with codes and standards	○	○	○	○	○
Driven by the need to balance engineering workload among multiple offices	○	○	○	○	○
Driven by the availability of engineers	○	○	○	○	○
Driven by the goal to expand detailing work for the same cost	○	○	○	○	○
Driven by developments in technology	○	○	○	○	○
Driven by the changing education/demographics	○	○	○	○	○
Driven by the need to maintain consistency of product/service	○	○	○	○	○
Driven by country, client, or funding source requirements	○	○	○	○	○
Driven by competitors	○	○	○	○	○
Driven by company policy, e.g., global procurement of services	○	○	○	○	○

7. How do you divide the scope of engineering work performed by a global engineering team on typical projects (check all that apply)?

- ☐ Split between project phases, e.g., schematic design, design development, detailed design, etc.
- ☐ Split between project components and/or systems

☐ The engineering is integrated within all groups

8. For projects performed by your company with Global Virtual Engineering Teams, what is the typical impact on:

	more than 10% increase	0-10% increase	Same	0-10% reduction	more than 10% reduction
ENGINEERING COST	○	○	○	○	○
CONSTRUCTION COST	○	○	○	○	○
ENGINEERING TIME	○	○	○	○	○
OVERALL PROJECT DELIVERY TIME	○	○	○	○	○
ENGINEERING QUALITY	○	○	○	○	○
CONSTRUCTION QUALITY	○	○	○	○	○

9. From your personal experience, list up to five of the most important factors that lead to successful/unsuccessful global virtual engineering teams?

	SUCCESS FACTORS	FAILURE FACTORS
1.		
2.		
3.		
4.		
5.		

SECTION II: ORGANIZATION

10. Does your home country governmental policy and regulations limit your ability to use global VT?

☐ Yes
☐ No

If yes, please provide example(s)?

11. How often does language cause problems on a project?

☐ Extremely frequent
☐ Very frequent
☐ Frequent

☐ Not frequent
☐ Never an issue

12. When using global virtual teams, how often do you have difficulty meeting P.E. licensing work supervision requirements?

☐ Frequently
☐ Not frequently
☐ Never

Comment:

SECTION III: TECHNOLOGY

13. Do you view technology as a major concern when considering global virtual teaming?

☐ Yes, technology frequently limits our VT implementation
☐ Sometimes technology limits our VT implementation
☐ No, adequate technology is readily available

14. What tools is your company currently using for administering global virtual engineering teams (check all that apply)?

☐ E-mail
☐ FTP
☐ Video-Conferencing
☐ Web-Conferencing
☐ Virtual Private Networking
☐ Project Specific Websites
☐ Applications for Simultaneous Remote Collaboration
☐ Common Repositories for Project Information
☐ Knowledge Management Systems, e.g.: lesson learned databases

15. Do you believe that the current status of collaborative technology fosters global virtual teaming?

☐ Yes, the technology readily supports global virtual teaming
☐ No, the technology is not addressing global virtual teaming well

16. Does your company have difficulties using collaborative tools when interacting with other organizations due to security / firewalls?

☐ No, our company does not engage in electronic collaborative work with other organizations
☐ No, we do not have firewalls
☐ No, we have firewalls and engage in electronic collaborative work, but we have not encountered problems

☐ Yes, we have experienced such problems in the past and have decided not to use the tools
☐ Yes, we have experienced such problems in the past, but we can work through them

SECTION IV: MANAGEMENT

17. How do global VT impact the "team" feeling for individuals who are geographically isolated from the majority of the group?

☐ No impact, team members have the same team feeling
☐ Global VT cause individual team members to feel LESS like an integrated team
☐ Global VT cause individual team members to feel MORE like a part of the team
☐ Other

Other:

18. What is the impact of global virtual teaming on members voicing opinions on project issues?

☐ Team members appear more comfortable in the electronic team
☐ Team members are less communicative in the electronic environment
☐ There appears to be no real difference in the VT
☐ Other

Other:

19. How do managers in your company compensate for not having the opportunity to sit down with a team member face-to-face to either congratulate or reprimand the team member for his or her efforts?

☐ Managers spend more time on the phone
☐ Managers use collaborative tools as a substitute
☐ Managers make visits to distributed team members
☐ Managers put more reviews in writing

20. What is the impact of global VT on trust between team members?

☐ Team members have more trust
☐ Team members have less trust
☐ No real difference

21. Does a Global VT increase the time spent by your project management team on the project?

☐ Yes
☐ No

If yes, estimate the additional time as a percent of total management time:

____ %

22. Does your company plan to increase, maintain, or decrease your implementation of Global Virtual Teaming?

- Increase
- Maintain
- Decrease

SECTION V: GENERAL COMMENTS

Please provide any other relevant comments, lessons learned, or best practices.

Are you willing to be interviewed by phone or in person for this study?

- Yes
- No

THANK YOU FOR YOUR TIME AND COOPERATION

Submit

Construction Industry Institute (CII)
CII PROJECT TEAM 211
The Pennsylvania State University

Your Survey Has Been Successfully Completed

THANK YOU VERY MUCH FOR COMPLETING THE SURVEY!

All information will be kept strictly confidential

Contact Information:

If you wish to obtain further information related to this study, please contact:

John I. Messner
Assistant Professor
Department of Architectural Engineering
104 Engineering Unit A
University Park, PA 16802
jmessner@engr.psu.edu

Website Links:

Dr. John I. Messner's homepage

CONSTRUCTION INDUSTRY INSTITUTE (CII)

APPENDIX B

EPC Organization Online Survey Instrument

Effective Use of Global Engineering Work Force Survey

FOR EPC ORGANIZATION

Construction Industry Institute (CII)
CII PROJECT TEAM 211
The Pennsylvania State University

This survey form is for EPC ORGANIZATIONS.
If you work for an Owner/Operator, please go to this link: Owner/Operator Survey
For the purpose of this survey, please only consider Global Virtual Teams that contain members located in at least two countries.

All information will be kept strictly confidential. By submitting this survey, you are consenting to participate in this research project. Further information regarding this consent can be found at: http://www.arche.psu.edu/faculty/JMessner/otherpages/consent.pdf

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3. What size projects (in total installed cost) has your company executed with global engineering teams? (check all that apply)

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☐ We are experimenting with global VT on our first project(s)
☐ We are not using global VT

5. If your company has used or is experimenting with global virtual teaming, what is the purpose f using the teams (check all that apply)?

☐ Communication inside the company
☐ Communication with subcontractors / vendors
☐ Communication with other project participants, e.g. Owner / Operator, Lender

6. What are the drivers for making decisions in improving the distribution of engineering work among the global engineering work force? (1 = least important & 5 = most important)

	1	2	3	4	5
Driven by the need to reduce engineering service cost	○	○	○	○	○
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Driven by the need to improve engineering quality	○	○	○	○	○
Driven by the need to locate services close to the project location	○	○	○	○	○
Driven by global customers or local customers	○	○	○	○	○
Driven by the need to understand/comply with codes and standards	○	○	○	○	○
Driven by the need to balance engineering workload among multiple offices	○	○	○	○	○
Driven by the availability of engineers	○	○	○	○	○
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Driven by developments in technology	○	○	○	○	○
Driven by the changing education/demographics	○	○	○	○	○
Driven by the need to maintain consistency of product/service	○	○	○	○	○
Driven by country, client, or funding source requirements	○	○	○	○	○
Driven by competitors	○	○	○	○	○
Driven by company policy, e.g., global procurement of services	○	○	○	○	○

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OVERALL PROJECT DELIVERY TIME	○	○	○	○	○
ENGINEERING QUALITY	○	○	○	○	○
CONSTRUCTION QUALITY	○	○	○	○	○

9. From your personal experience, list up to five of the most important factors that lead to successful/unsuccessful global virtual engineering teams?

	SUCCESS FACTORS	FAILURE FACTORS
1.		
2.		
3.		
4.		
5.		

SECTION II: ORGANIZATION

10. Does your company have permanent domestic and overseas engineering design offices participating in global virtual teaming?

☐ Yes
☐ No
☐ We are in the process of forming an office at this time

If yes, please list the location of your engineering offices, number of engineers in each office, and their structure.

	Geographic Location	Number of Engineers	Structure of Office (Sole venture, Joint venture, Strategic alliance, etc.)
1.			
2.			

3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

11. Does your home country governmental policy and regulations limit your ability to use global V

☐ Yes
☐ No

If yes, please provide example(s)?

12. On a typical project with Global VT, how is your engineering productivity impacted in comparison to similar projects performed in the domestic environment?

☐ Increased
☐ The same
☐ Decreased

Estimate the increased or decreased % of productivity:

____ %

13. On average, is it more difficult to satisfy the owner's requirements with a global VT?

○ Yes ○ No

Comment:

14. How often does language cause problems on a project?

☐ Extremely frequent
☐ Very frequent

☐ Frequent
☐ Not frequent
☐ Never an issue

15. When using global virtual teams, how often do you have difficulty meeting P.E. licensing work supervision requirements?

☐ Frequently
☐ Not frequently
☐ Never

Comment:

SECTION III: TECHNOLOGY

16. Do you view technology as a major concern when considering global virtual teaming?

☐ Yes, technology frequently limits our VT implementation
☐ Sometimes technology limits our VT implementation
☐ No, adequate technology is readily available

17. What tools is your company currently using for administering global virtual engineering team: (check all that apply)?

☐ E-mail
☐ FTP
☐ Video-Conferencing
☐ Web-Conferencing
☐ Virtual Private Networking
☐ Project Specific Websites
☐ Applications for Simultaneous Remote Collaboration
☐ Common Repositories for Project Information
☐ Knowledge Management Systems, e.g.: lesson learned databases

18. Do you believe that the current status of collaborative technology fosters global virtual teamin;

☐ Yes, the technology readily supports global virtual teaming
☐ No, the technology is not addressing global virtual teaming well

19. Does your company have difficulties using collaborative tools when interacting with other organizations due to security / firewalls?

☐ No, our company does not engage in electronic collaborative work with other organizations
☐ No, we do not have firewalls
☐ No, we have firewalls and engage in electronic collaborative work, but we have not encountered problems

☐ Yes, we have experienced such problems in the past and have decided not to use the tools
☐ Yes, we have experienced such problems in the past, but we can work through them

SECTION IV: MANAGEMENT

20. How do global VT impact the "team" feeling for individuals who are geographically isolated fr the majority of the group?

☐ No impact, team members have the same team feeling
☐ Global VT cause individual team members to feel LESS like an integrated team
☐ Global VT cause individual team members to feel MORE like a part of the team
☐ Other

Other:

21. What is the impact of global virtual teaming on members voicing opinions on project issues?

☐ Team members appear more comfortable in the electronic team
☐ Team members are less communicative in the electronic environment
☐ There appears to be no real difference in the VT
☐ Other

Other:

22. How do managers in your company compensate for not having the opportunity to sit down wit team member face-to-face to either congratulate or reprimand the team member for his or her efforts?

☐ Managers spend more time on the phone
☐ Managers use collaborative tools as a substitute
☐ Managers make visits to distributed team members
☐ Managers put more reviews in writing

23. What is the impact of global VT on trust between team members?

☐ Team members have more trust
☐ Team members have less trust
☐ No real difference

24. Does a Global VT increase the time spent by your project management team on the project?

☐ Yes
☐ No

If yes, estimate the additional time as a percent of total management time:

☐ %

25. Does your company plan to increase, maintain, or decrease your implementation of Global Virtual Teaming?

- ○ Increase
- ○ Maintain
- ○ Decrease

SECTION V: GENERAL COMMENTS

Please provide any other relevant comments, lessons learned, or best practices.

Are you willing to be interviewed by phone or in person for this study?

- ☐ Yes
- ☐ No

THANK YOU FOR YOUR TIME AND COOPERATION

Submit

APPENDIX C

Comprehensive Survey Results

Survey Results

This appendix includes a compilation of all the results from the industry survey questions.

<u>Respondent Information:</u>

- Total number of responses: 46
  - **OWNER** : 19
  - **EPC** : 27

- CII member companies: 32
  - **OWNER :** 13
  - **EPC :** 19

- Non-CII companies: 1
  - **OWNER :** 0
  - **EPC :** 1

1. How many years of experience do you (personally) have with global virtual engineering teams (may be with different organizations/companies)?

Owner		
Result	**Responses**	**Percentage**
None	6	31.5%
< 1 year	1	5.2%
1 to 5 years	9	47.3%
> 5 years	3	15.7%
EPC		
Result	**Responses**	**Percentage**
None	2	7.4%
< 1 year	0	0.0%
1 to 5 years	10	37.0%
> 5 years	15	55.5%

2. How many years of experience does your company have with global virtual engineering teams?

Owner		
Result	**Responses**	**Percentage**
None	5	26.3%
< 1 year	0	0.0%

1 to 5 years	4	21.0%
> 5 years	10	52.6%
EPC		
Result	**Responses**	**Percentage**
None	1	3.7%
< 1 year	0	0.0%
1 to 5 years	9	33.3%
> 5 years	17	62.9%

3. What size projects (in total installed cost) has your company executed with global engineering teams? (Check all that apply)

Owner		
Result	**Responses**	**Percentage**
Up to US$ 5 million	2	10.5%
US$ 5-20 million	5	26.3%
US$ 20-100 million	7	36.8%
More than US$ 100 million	9	47.3%
EPC		
Result	**Responses**	**Percentage**
Up to US$ 5 million	11	40.7%
US$ 5-20 million	7	25.9%
US$ 20-100 million	10	37.0%
More than US$ 100 million	15	55.5%

4. During the engineering process for capital projects, how frequently does your company use global virtual teaming (VT)?

Owner		
Result	**Responses**	**Percentage**
We use global VT as an integral part of all projects	1	5.2%
We use global VT on many projects	11	57.8%
We are experimenting with global VT on our first project(s)	2	10.5%
We are not using global VT	5	26.3%
EPC		
Result	**Responses**	**Percentage**
We use global VT as an integral part of all projects	2	7.4%
We use global VT on many projects	18	66.6%
We are experimenting with global VT on our first project(s)	5	18.5%
We are not using global VT	2	7.4%

5. If your company has used or is experimenting with global virtual teaming, what is the purpose for using the teams (check all that apply)?

Owner		
Result	**Responses**	**Percentage**
Communication inside our Organization	7	36.8%
Communication with Engineering/Construction Organizations	15	78.9%
EPC		
Result	**Responses**	**Percentage**
Communication inside the company	19	70.3%
Communication with subcontractors / vendors	7	25.9%
Communication with other project participants, e.g. Owner / Operator, Lender	15	55.5%

6. What are the drivers for making decisions in improving the distribution of engineering work among the global engineering work force? (1 = least important & 5 = most important)

Drivers	Owner							EPC							Total	
	%					Score	Rank	%					Score	Rank	Score	Rank
	1	2	3	4	5			1	2	3	4	5				
Driven by the need to reduce engineering service cost	0	17	11	17	56	4.10	1	0	4	4	26	67	4.55	1	4.3	1
Driven by competitors	39	11	17	22	11	2.55	7	0	7	26	37	30	3.89	2	3.2	2
Driven by global customers or local customers	29	6	18	41	6	2.87	6	11	11	15	41	22	3.52	3	3.2	3
Driven by the need to locate services close to the project location	12	0	35	41	12	3.40	2	22	19	26	26	7	2.78	7	3.1	4
Driven by the need to reduce the engineering schedule	22	11	28	28	11	2.94	4	22	22	15	30	11	2.85	6	2.9	5
Driven by the goal to expand detailing work for the same cost	18	12	35	29	6	2.93	5	15	33	19	30	4	2.74	8	2.8	6
Driven by country, client, or funding source requirements	35	24	12	24	6	2.40	9	15	22	15	33	15	3.11	5	2.8	7
Driven by the need to understand/comply with codes and standards	29	6	24	12	29	3.05	3	30	15	44	11	0	2.37	12	2.7	8
Driven by company policy, e.g., global procurement of services	41	12	24	12	12	2.40	10	15	26	37	19	4	2.70	9	2.6	9
Driven by the need to balance engineering workload among multiple offices	41	35	18	6	0	1.88	15	7	15	37	37	4	3.15	4	2.5	10
Driven by developments in technology	35	29	12	18	6	2.29	12	30	15	26	30	0	2.55	11	2.4	11
Driven by the availability of engineers	41	6	35	18	0	2.29	13	26	15	37	19	4	2.59	10	2.4	12
Driven by the need to improve engineering quality	28	17	28	28	0	2.55	8	48	11	26	11	4	2.11	14	2.3	13
Driven by the need to maintain consistency of product/service	35	24	12	24	6	2.40	11	37	26	26	11	0	2.11	13	2.3	14
Driven by the changing education/demographics	41	18	18	24	0	2.23	14	30	44	19	7	0	2.04	15	2.1	15

7. How do you divide the scope of engineering work performed by a global engineering team on typical projects (check all that apply)?

Owner		
Result	**Responses**	**Percentage**
Split between project phases, e.g., schematic design, design development, detailed design, etc.	11	57.8%
Split between project components and/or systems	11	57.8%
The engineering is integrated within all groups	7	36.8%
EPC		
Result	**Responses**	**Percentage**
Split between project phases, e.g., schematic design, design development, detailed design, etc.	20	74.0%
Split between project components and/or systems	19	70.3%
The engineering is integrated within all groups	10	37.0%

8. For projects performed by your company with Global Virtual Engineering Teams, what is the typical impact on:

	OWNER					EPC				
	more than 10% increase	0-10% increase	Same	0-10% reduction	more than 10% reduction	more than 10% increase	0-10% increase	Same	0-10% reduction	more than 10% reduction
ENGINEERING COST	7.1	0	7.1	35.7	50.0	0	3.8	7.6	42.3	46.1
CONSTRUCTION COST	0	7.1	71.4	14.2	7.1	0	0	79.1	20.8	0
ENGINEERING TIME	0	7.1	57.1	28.5	7.1	4.0	28.0	40.0	20.0	8.0
OVERALL PROJECT DELIVERY TIME	0	14.2	57.1	28.5	0	0	4.0	60.0	32.0	4.0
ENGINEERING QUALITY	7.1	14.2	57.1	21.4	0	4.0	8.0	72.0	16.0	0
CONSTRUCTION QUALITY	0	21.4	64.2	14.2	0	4.1	16.6	79.1	0	0

9. From your personal experience, list up to five of the most important factors that lead to successful/unsuccessful global virtual engineering teams?

OWNER & EPC	
SUCCESS FACTORS	**FAILURE FACTORS**
1) Clear & frequent communication, periodic face-to-face meetings (16)	1) Lack of or poor communication, face-to-face meetings (19)
2) Good communications tools and IT compatibility (15)	2) Lack of understanding of local work practices, cultural differences, and/or language issues (14)
3) Standard work processes and communication procedures (11)	3) Lack of management involvement, experienced leadership (9)
4) Clearly defined scope & expectations (10)	4) Changes (goal, scope), slow response to change (8)
5) Clearly defined roles and responsibilities (9)	5) Incompatible or poor technology including, hardware and software (7)
6) Detailed and complete execution plans (9)	6) Lack of trust (6)
7) Management involvement, competent management, management oversight, strong leadership (7)	7) Lack of appropriate skills, inexperience (5)
8) Commitment, motivation (5)	8) Unreasonable expectations (5)
9) Early involvement in FEL (4)	9) Missing standards, no common methodology (5)
10) Common project goal/objectives (4)	10) Lack of clarity on scope, poor scope definition (4)
11) Local coordination for overseas engineering firm (3)	11) Poor planning (4)
12) Continuity of staffing on global team, good exchange program (3)	12) Unclear split of work responsibilities between offices (3)
13) Flexible personnel (3)	13) Poor Coordination (2)
14) Relocation of few key people to collaborating offices (2)	
15) Expatriates deployed to foreign sites (2)	
16) Documenting work processes, procedures (2)	
17) Infrastructure in place before the project starts (2)	
18) Training (2)	

10. Does your company have permanent domestic and overseas engineering design offices participating in global virtual teaming?

EPC		
Result	**Responses**	**Percentage**
Yes	20	74.0%
No	4	14.8%
We are in the process of forming an office at this time	5	18.5%

If yes, please list the location of your engineering offices, number of engineers in each office, and their structure.		
Geographic Location	**Number of Engineers**	**Structure of Office (Sole venture, Joint venture, Strategic alliance, etc.)**
Houston, TX (2)	200, 700	Sole Venture
Bloomfield, NJ	100	Sole Venture
Mexico (6)	200, 200, 200, 50, 30, 20	Wholly Owned, Alliance, Strategic Alliance, Partial Ownership, Joint Venture
Multiple Operating Centers – Domestic & International	50 – 1500	Sole Venture
Czech Republic (2)	350, ?	Company Subsidiary, Sole Venture
Russia (3)	600, 40, ?	Partial Ownership, Joint Venture, Joint Venture, Sole Venture
Singapore (1)	120	Company Subsidiary, Sole Venture
China (4)	200, 30, ?	Joint Venture, Strategic Alliance
India (10)	400, ~300, 300, 300, 200, 200+, ~75, 40, 20, ?	Partial Ownership, Joint Venture, Equity position, Alliance, Sole Venture, Wholly Owned
Estonia	20	Wholly Owned Subsidiary
Romania (2)	20, 125	Joint Venture, Subsidiary
50 domestic offices	10 to 200 per office	Sole Venture

20 international offices	5 to 30 engineers	Sole Venture
5 domestic offices	10 engineers per office	Joint Venture
Chile	200	Joint Venture
USA	~110	Strategic Alliance
Poland (2)	28, ~400	Sole Venture
London (2)	800, 40	Sole Venture
UAE (2)	200, 150	Sole Venture
Pennsylvania	900	Sole Venture
California	400	Sole Venture
Finland	200	Sole Venture
Argentina	275	Wholly Owned
New Zealand	300	Joint Venture
Asia	~30	Strategic Alliance
Brazil	75	Wholly Owned
Philippines	~300, ~20	Sole Venture, Wholly Owned
Oman	150	Joint Venture
Canada (2)	200, 50	Joint Venture, Sole Venture
Bangkok	60	Sole Venture
Taiwan	110	Sole Venture
Malaysia	20	Sole Venture
Saudi Arabia	200	Joint Venture

10. Does your home country governmental policy and regulations limit your ability to use global VT?

Owner		
Result	**Responses**	**Percentage**
Yes	0	0.0%
No	18	100.0%
EPC		
Result	**Responses**	**Percentage**
Yes	7	26.9%
No	19	73.0%

If yes, please provide example(s)?
Export Controls, Export Compliance Issues, DCAA auditing and FAR requirements, Protection of Intellectual Property Rights, In some cases, US Trade Compliance limits the transfer of technology (both internal and client) to other countries and foreign nationals, Increasing restrictions on Visa for travel to USA restricts flow of project team personnel at various stages on project.
Establishment of quotas for H & L visas.
Not directly although we have a member of the French government on the board.

12. On a typical project with Global VT, how is your engineering productivity impacted in comparison to similar projects performed in the domestic environment?

EPC		
Result	**Responses**	**Percentage**
Increased	5	18.5%
The same	11	40.7%
Decreased	11	40.7%

Estimate the increased or decreased percent of productivity:
35%, 25%, 20%, 10% : Increased
40%, 25%, 20%, 15%, 10%, 5% : Decreased

13. On average, is it more difficult to satisfy the owner's requirements with a global VT?

EPC		
Result	**Responses**	**Percentage**
Yes	11	42.3%
No	15	57.6%

Comment:
More oversight and coordination is required to ensure requirements are satisfied. We try to make the use of VT's transparent to our clients.

Owners are more comfortable with local engineering resources. Global VT engineering teams are remote and don't give the personal touch local resources can give. Many owners want the work done where they can see progress.

Usually requires more project management and technical lead time (hours) to manage the same scope. As we work closer with our off-shore engineering center partners and develop common standards, this is improving over time.
Particular attention always has to be placed on clearly defining expectations, product requirements and schedules.

11. How often does language cause problems on a project?

Owner		
Result	**Responses**	**Percentage**
Extremely frequent	0	0.0%
Very frequent	2	11.7%
Frequent	4	23.5%
Not frequent	9	52.9%
Never an issue	2	11.7%
EPC		
Result	**Responses**	**Percentage**
Extremely frequent	1	3.7%
Very frequent	1	3.7%
Frequent	11	40.7%
Not frequent	14	51.8%
Never an issue	0	0.0%

12. When using global virtual teams, how often do you have difficulty meeting P.E. licensing work supervision requirements?

Owner		
Result	**Responses**	**Percentage**
Frequently	0	0.0%
Not frequently	9	64.2%
Never	5	35.7%
EPC		
Result	**Responses**	**Percentage**
Frequently	3	11.5%

Not frequently	21	80.7%
Never	2	7.6%

Comment:
The US based engineers that work for the EPC have the proper credentials

The A&E companies we hire to develop the specific construction drawings and packages stamp the drawings.

This is a situation that is being addressed by all of the State Engineering licensing boards. Several states have already made it difficult to use off-shore engineering.

Many of the states require the PE to be in responsible charge of the work and some states even require the work to be done in the same office location as the PE.

Generally the home office reviews and oversees the work by the remote office to the extent necessary to meet P.E. license requirements.

We have PEs of the other country there and also in the US.

13. Do you view technology as a major concern when considering global virtual teaming?

Owner		
Result	**Responses**	**Percentage**
Yes, technology frequently limits our VT implementation	2	11.7%
Sometimes technology limits our VT implementation	4	23.5%
No, adequate technology is readily available	11	64.7%
EPC		
Result	**Responses**	**Percentage**
Yes, technology frequently limits our VT implementation	2	7.6%
Sometimes technology limits our VT implementation	10	38.4%
No, adequate technology is readily available	14	53.8%

14. What tools is your company currently using for administering global virtual engineering teams (check all that apply)?

Result	OWNER		EPC	
	Responses	Percent	Response	Percent
E-mail	15	93.7%	27	100.0%
FTP	5	31.2%	16	59.2%
Video-Conferencing	11	68.7%	21	77.7%
Web-Conferencing	10	62.5%	15	55.5%
Virtual Private Networking	4	25.0%	16	59.2%
Project Specific Websites	10	62.5%	22	81.4%
Applications for Simultaneous Remote Collaboration	5	31.2%	17	62.9%
Common Repositories for Project Information	14	87.5%	20	74.0%
Knowledge Management Systems, e.g.: lesson learned databases	6	37.5%	18	66.6%

15. Do you believe that the current status of collaborative technology fosters global virtual teaming?

Owner		
Result	**Responses**	**Percentage**
Yes, the technology readily supports global virtual teaming	16	94.1%
No, the technology is not addressing global virtual teaming well	1	5.8%
EPC		
Result	**Responses**	**Percentage**
Yes, the technology readily supports global virtual teaming	24	88.8%
No, the technology is not addressing global virtual teaming well	3	11.1%

16. Does your company have difficulties using collaborative tools when interacting with other organizations due to security / firewalls?

Result	OWNER		EPC	
	Responses	Percentage	Responses	Percentage
No, our company does not engage in electronic collaborative work with other organizations	1	6.2%	1	3.7%
No, we do not have firewalls	0	0.0%	0	0.0%
No, we have firewalls and engage in electronic collaborative work, but we have not encountered problems	4	25.0%	7	25.9%
Yes, we have experienced such problems in the past and have decided not to use the tools	0	0.0%	1	3.7%
Yes, we have experienced such problems in the past, but we can work through them	11	68.7%	18	66.6%

17. How does global VT impact the "team" feeling for individuals who are geographically isolated from the majority of the group?

OWNER		
Result	**Responses**	**Percentage**
No impact, team members have the same team feeling	3	20.0%
Global VT cause individual team members to feel LESS like an integrated team	11	73.3%
Global VT cause individual team members to feel MORE like a part of the team	1	6.6%
Other	0	0.0%
EPC		
Result	**Responses**	**Percentage**
No impact, team members have the same team feeling	4	16.0%
Global VT cause individual team members to feel LESS like an integrated team	17	68.0%
Global VT cause individual team members to feel MORE like a part of the team	1	4.0%
Other	3	12.0%

Other:

It helps if there is a face to face meeting somewhere along the project (ideally early on). Once a relationship is established, team feels integrated.

The key is getting the lead engineers on both sides close to each other during the entire project.

Mostly dependent on the local project management to foster team building

There is more of a negative impact on the home office engineers as they see more and more work being pushed offshore and less engineering being done in the home office. This often times results in staff reductions and they see their friends and coworkers being caught in lay offs.

This is dependent on the way the project is split. If by phases, the integration will be more at leadership and interface levels, not in totality.

Has to be addressed in the early stages of the project. Failure to address the isolation or "us v. them" mentality is a leading failure mode in the use of this kind of team.

This can also be a cultural issue.

18. What is the impact of global virtual teaming on members voicing opinions on project issues?

Owner		
Result	**Responses**	**Percentage**
Team members appear more comfortable in the electronic team	1	6.6%
Team members are less communicative in the electronic environment	11	73.3%
There appears to be no real difference in the VT	2	13.3%
Other	1	6.6%
EPC		
Result	**Responses**	**Percentage**
Team members appear more comfortable in the electronic team	6	22.2%
Team members are less communicative in the electronic environment	10	37.0%
There appears to be no real difference in the VT	6	22.2%
Other	5	18.5%

Other:

Can sometime be a problem since it is easier to be critical and negative through electronic communication (e-mail can be used as a weapon). Tend to get the point quicker. Minor issues risk becoming major e-mail wars and consequently team-busters, especially where time zones impede real time conversations

Issues may not be as readily surfaced as in face-to-face project meetings.

Members can be more willing to state issues in the remote environment due to the absence of personal interfaces and inhibitions. While this can be good in terms of fostering more open communications, it can also lead to misunderstandings and conflicts that may been avoided had the personal contact with social interaction been present

More means than just electronic is needed for some issues. You still need face-to-face for some issues.

19. How do managers in your company compensate for not having the opportunity to sit down with a team member face-to-face to either congratulate or reprimand the team member for his or her efforts?

Owner		
Result	**Responses**	**Percentage**
Managers spend more time on the phone	6	46.1%
Managers use collaborative tools as a substitute	6	46.1%
Managers make visits to distributed team members	7	53.8%
Managers put more reviews in writing	4	30.7%
EPC		
Result	**Responses**	**Percentage**
Managers spend more time on the phone	17	62.9%
Managers use collaborative tools as a substitute	11	40.7%
Managers make visits to distributed team members	16	59.2%
Managers put more reviews in writing	3	11.1%

20. What is the impact of global VT on trust between team members?

Owner		
Result	**Responses**	**Percentage**
Team members have more trust	1	7.1%
Team members have less trust	8	57.1%
No real difference	5	35.7%
EPC		
Result	**Responses**	**Percentage**
Team members have more trust	1	3.8%
Team members have less trust	16	61.5%
No real difference	9	34.6%

21. Does a Global VT increase the time spent by your project management team on the project?

Owner		
Result	**Responses**	**Percentage**
Yes	6	42.8%
No	8	57.1%
If yes, estimate the additional time as a percent of total management time: 25%, 20%, 15+%, 15%, 10%, 3-5%		
EPC		
Result	**Responses**	**Percentage**
Yes	21	77.7%
No	6	22.2%
If yes, estimate the additional time as a percent of total management time: 75%, 40%, 25%, 20%, 15%, 10%, 5%, 2%		

22. Does your company plan to increase, maintain, or decrease your implementation of Global Virtual Teaming?

Owner		
Result	**Responses**	**Percentage**
Increase	11	68.7%
Maintain	5	31.2%
Decrease	0	0.0%
EPC		
Result	**Responses**	**Percentage**
Increase	25	92.5%
Maintain	2	7.4%
Decrease	0	0.0%

Please provide any other relevant comments, lessons learned, or best practices.

OWNER

- Offshore design done only when major equipment vendors are offshore

- Have acquired Eastern European operations, including their large internal design engineering organization. Are currently looking at ways of leveraging this asset to use for domestic project design and take advantage of low wage rates.

- other things going on simultaneously make it difficult to draw conclusions.

- Downsizing of owner engineering organizations are forcing some of this VT decisions and people are being asked to do more with less resources.

- some of the questions around trust, time management, quality are clouded by downsizing outfall

- Its all about good, clear, concise, and timely communications no matter how the project is accomplished

- We have not used and do not plan to use global teams with developing countries as a means to reduce engineering costs. Much of our global teaming is driven by our use of modular construction techniques

- the cost advantage of using a low-cost engineering center is partially offset by the cost of qualified supervision at the site. This should come down as low-cost sites gain experience and develop management skills.

EPC

- We currently have aggressive goals to increase both engineering productivity and off-shore engineering utilization to reduce cost. We would be very interested in how other organizations are doing in this area and what specific collaboration methods/tools are being successfully employed.

- The best environment is a captive off-shore company or partner. Many off-shore companies have the skills, but are they a cultural fit for your clients and the project team?

- Beware of passive resistance The quality of the deliverable is as good as the quality of the work package Frequent communication leads to quality deliverables Prototyping bulk deliverables as a quality checkpoint before large bulk deliveries are executed is a prudent step in terms of quality control Active teambuilding skills are essential to success Swapping key resources between global team locations to understand how the other half lives leads to better understanding and better quality deliverables.

- VT is a cost effective practice but requires large increases of management and oversight time.

- We have operated multiple site design teams for more than 15 years. Typically we may have mechanical balance of plant design in France, Electrical balance of plant design in UK, Project management in Switzerland and product package design and manufacture in say USA, China, South Korea etc. These teams are coordinated electronically using in house intranet systems, key player team meetings a large number of phone calls. With the increasing cost pressures and increasing risks of EPC projects we are trying to find new ways to reduce our cost base by moving aspects of the design process to low cost labor countries such as India. A fresh look is being taken of the tools in place and of the changing culture of the people using them. As project teams get more and more remote, it becomes more and more important for the systems in place to offer full transparency of performance or for other softer methods to be found to ensure that all participants re communicating properly. In you questions you have not considered culture or leadership as factors in the effective management of globalized teams? Secondly in Europe it is not un common for any project to involve at least two countries however the convenience of a short flight and the same time zone rule out many of the problems that can occur across more diverse cultures or distances.

- The use of Low Cost Engineering Centers (LCECs) has emerged as a common practice by many EPC contractors today. This has been driven by the recognition that a significant portion of the detail design effort can be treated as a commodity. While this practice is not a new concept, recent years have seen significant increase in the overall implementation and capability of the LCECs. Increasing advancements in technology for work sharing and collaborative design, will make LCECs a necessity for at least the near future. It is a capability being driven by the need to lower project costs in all project sectors. However, utilization of LCECs is not the only driver for improved work sharing methods. International projects require local content and contractors must integrate this element into the overall project execution. In addition, project teams are comprised of strategic partners that include owners, EPC contractors, suppliers and specialty contractors. Significant project performance improvement is possible through the utilization of innovative work sharing techniques to facilitate better information flow, utilization of competencies and overall execution responsibilities. To be successful, EPC contractors will need to re-cast the roles of project participants and remove the paradigms of traditional execution. These paradigms will be replaced with a new set of expectations and responsibilities and people will need to be trained and coached through the process. Tools and systems must be put in place to assess progress, review work and exchange information remotely and efficiently. As globalization continues to take hold, contractors should have the goal to become best in class at work sharing and integrating external project participants into the project delivery process. Working virtually puts new demands on project teams and typically it is the social issues that are underestimated. It has been my experience that the technology is adequate, but teams seldom communicate enough and maintain sufficient emphasis on information flow and control.

Are you willing to be interviewed by phone or in person for this study?

Owner		
Result	**Responses**	**Percentage**
Yes	13	72.2%
No	5	27.7%
EPC		
Result	**Responses**	**Percentage**
Yes	23	85.1%
No	4	14.8%

APPENDIX D

Interview Questions

Interview Questions

This section contains questions that were asked during the initial interviews. All the questions are structured with a main question and possible follow-up questions. Further questions were asked to elucidate on issues as discussed by the interviewees.

Background Information:

1. What is your title and responsibilities in your company?
2. How many years of experience do you (personally) have with global virtual engineering teams (may be with different organizations/companies)?
3. How many years of experience does your company have with global virtual engineering teams?
4. Were you involved in the decision-making stage when your company chose to structure their use of the global engineering work force for a particular project?

Organizational Level Decision:

1. Have you opened any permanent overseas engineering offices? If so, why have you opened them? Where are they located and how large are they?
    a. What are labor cost rates for different geographic regions?
    b. What were the start-up costs for your international office(s)?
    c. What items did you consider when opening the permanent office?
    d. How much work (as % or $ value) do you perform in each office?

2. Has there been any negative reaction from your domestic engineers related to your opening of international office?

Project Level Decision:

1. What items do you consider when deciding whether to use engineers located in other countries to perform engineering services on your projects?
    a. How do you consider each item? What quantitative and qualitative method do you use?
    b. Is intellectual property a significant concern for your company that impacts your decision to use non-domestic engineers?

2. Does your company have a systematic process to guide the executives when determining the location that the engineering services for a particular project will be performed?
    a. What information and factors are considered in this decision process?

   b. How are they considered?

3. How do you select the location (either regions or countries) in which you perform the engineering services for a project?

4. How do you typically distribute the work?
   a. Is it by phase, by system, or some other method?
   b. Please provide an example.
   c. How do you make this work distribution decision?

Best Practices for Successful Implementation:

1. What do you feel are the critical items that allow you to be successful at developing effective global engineering teams?

2. To obtain a better understanding on the best practices for the successful implementation of global virtual teaming, we have divided best practices into the six categories: Technology, Management, Strategy, Organization, Economics, and Institution.

   - In Technology
     - What do you believe are the critical technology factors for being successful at effectively implementing global engineering teams?
     - Do you feel that real-time collaborative technologies are mandatory for effective communication?

   - In Management
     - What do you feel are the key success factors for effectively managing the team members?

   - In Strategy
     - How important is it that your global engineering approach fit within your corporate strategy?

   - In Organization
     - Is there a particular organizational structure that you feel is best used for effectively implementing global engineering teams?
     - What are the key elements in that structure that is imperative for success?

   - Economics:
     - With regards to costs & benefits, how do you or when do you characterize that the use of global engineering work force is a success?

- Institution:
  - Does your company have well defined, written policies for managing your global engineering team? How important do you feel these formal policies are to the success of a team?

3. Do you feel that technology is limiting your ability to effectively administer projects with engineering teams that are geographically dispersed?
   a. How well is the project control tools integrated?
   b. Do you use a standard technology process for administering projects?
   c. Do owners frequently define technology specifications?

4. How do you manage dispersed teams of engineers?
   a. Who do the engineers report to?
   b. How do you transition between project phases?
   c. What is your quality control approach?
   d. Could you describe the frequency of coordination meetings, first meeting timing and duration, and early involvement of key functional leaders?
   e. Could you describe your company's team building process, training (both in work processes and company culture), and morale building for engineers that are not collocated with the core team?
   f. How do you recognize and reward good performance with global virtual teams?
   g. What is the impact of language and cultural difference between locations? How do you manage them?

Case Study Examples:

1. Could you give me an example of a successful project that was executed based on the effective use of engineers from another country?
   a. What were the project characteristics, for example the size and type of the project, type of contract, etc?
   b. Why do you consider the project a success?

2. Could you provide an example of an unsuccessful project, if any? Please share a few thoughts on the lessons learned from the project.

Concluding Questions:

1. What is the current trend within your company toward performing more projects with global virtual teams?

2. Do you have any additional comments or items that you feel are important for our research team to consider?

APPENDIX E

Case Study Interview Questions

Case Study Interview Questions

This section contains questions that were asked during the case study interview with one of the CII member company. All the questions are structured with a main question and possible follow-up questions. Further questions were asked to elucidate on issues as discussed by the interviewees.

Background Information:

1. What is your title and responsibilities in your company?
2. How many years of experience do you (personally) have with global virtual engineering teams (may be with different organizations/companies)?
3. How many years of experience does your company have with global virtual engineering teams?
4. Were you involved in the decision-making stage when your company chose to structure their use of the global engineering work force for this case study project?

How did you develop virtual teaming strategy for the project?

1. Why did you use global virtual teaming strategy?
2. Could you clearly define the work breakdown structure?
3. What was the contracting structure?

How did you develop project virtual teaming infrastructure for the project?

1. How did you develop information technology infrastructure for this project?
2. Please define the project execution/procedures plan.
3. How did you manage time zone differences?

How did you build the global virtual team?

1. How did you organize the team? How did you identify the team members that were required for this project?
2. What steps were taken in order to familiarize members with work process and culture in other location?
3. How did you build trust within the project team?
4. Please define the reward system used for this project?

How did you manage VT operations?

1. How did you ensure that proper quality control reviews and licensor requirements were met?
2. Did you organize frequent communication between locations? How?
3. Was there continuous monitoring at the remote office once the first phase of the project was transferred from the main office?
4. How did you monitor progress and performance?

Other information we would like to touch upon are regarding:

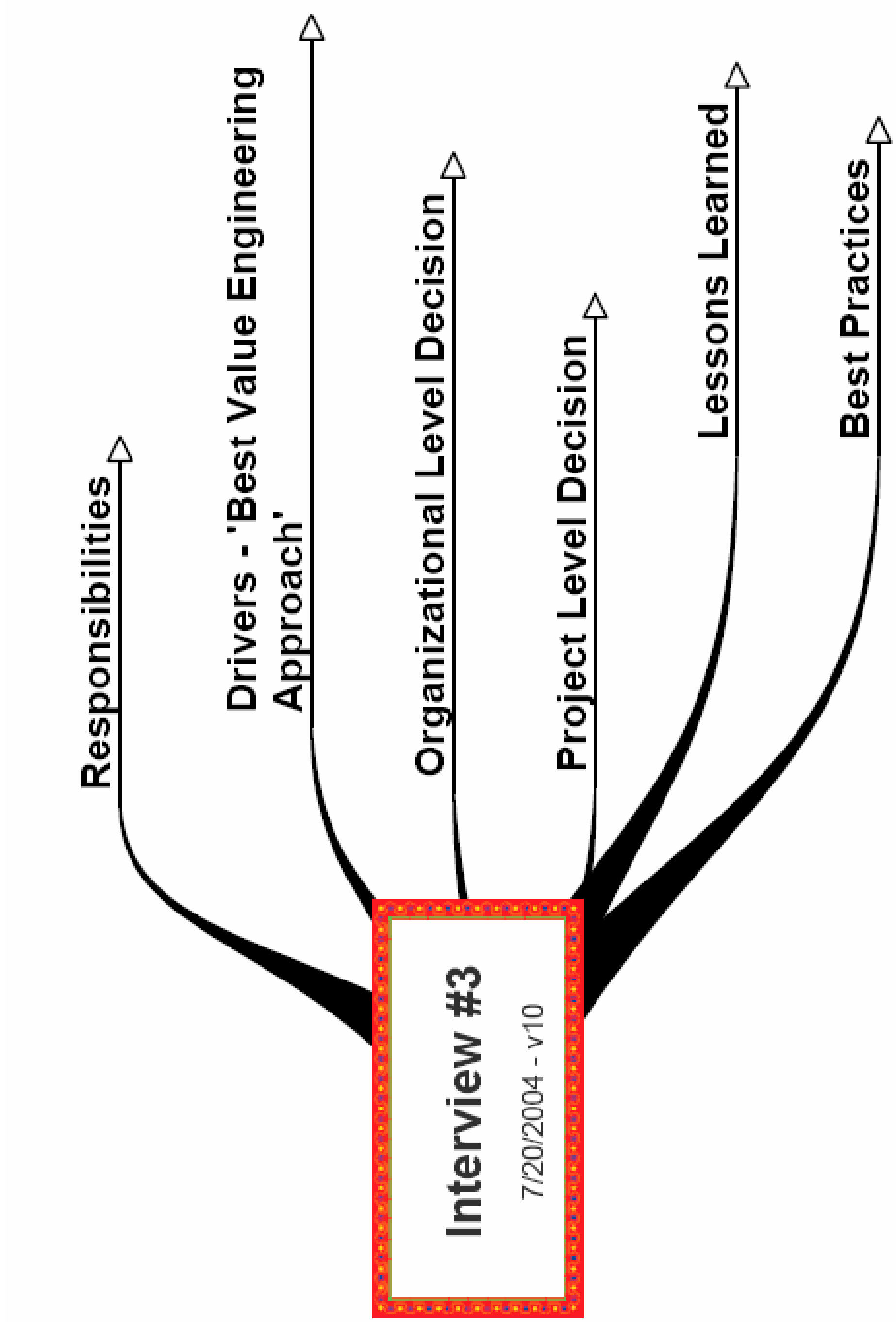
- Communications setup, package work, timetable, skills, wage rates, details on specific systems, country of engineers, how many, location of project, local content issues.
- Was it effective? Level of quality, cost savings
- What would you do different?
- Key success items for this project

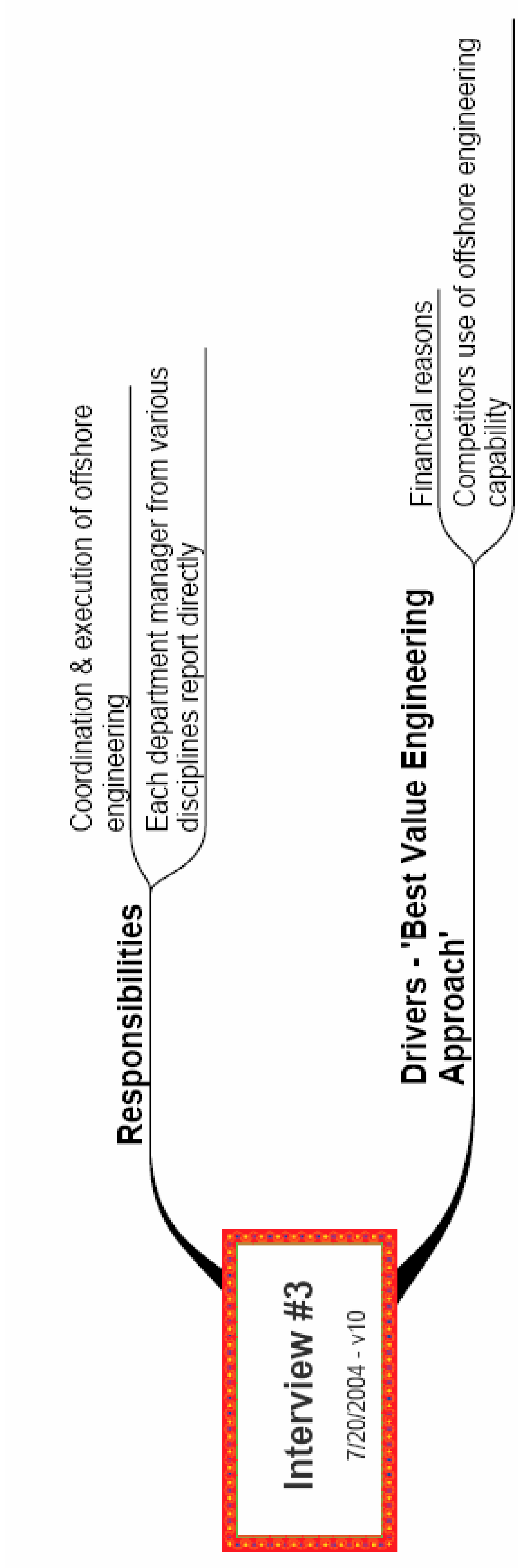
Concluding Questions:

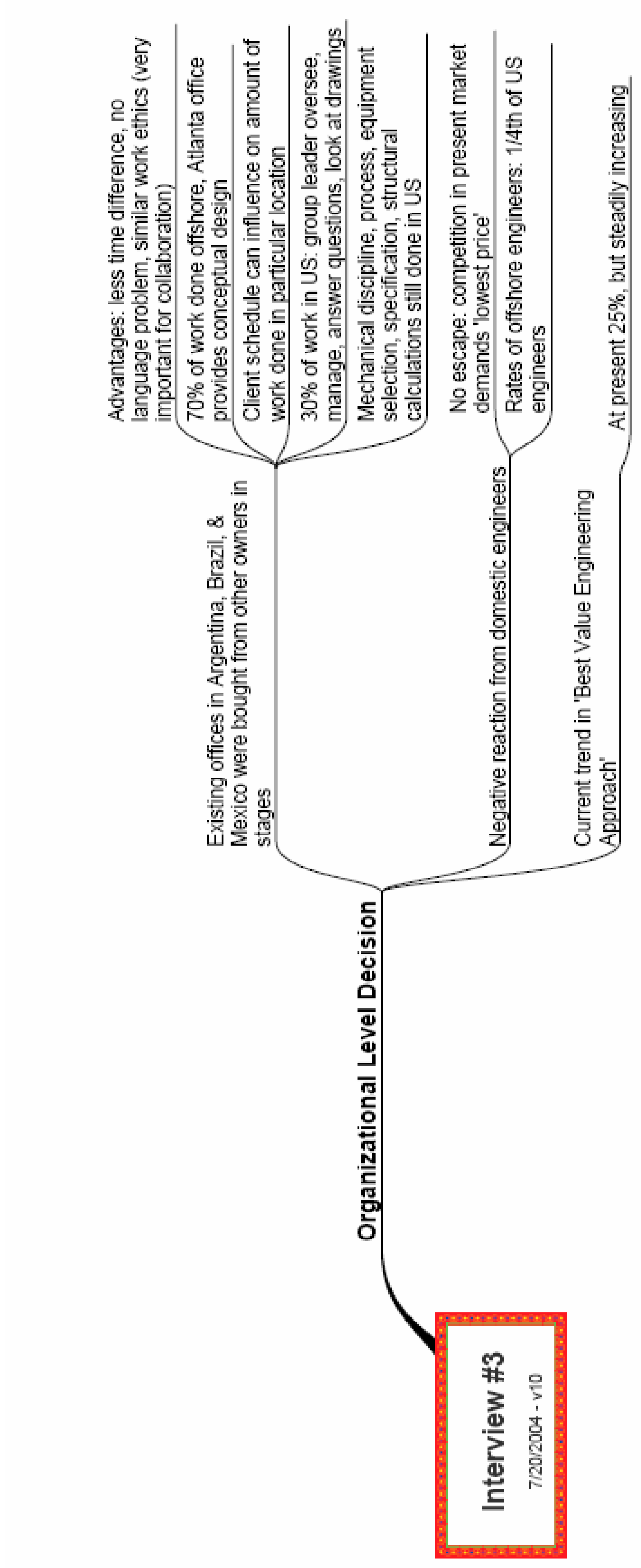
1. What is the current trend within your company toward performing more projects with global virtual teams?
2. Does your company have well equipped leaders to manage this new trend of dispersed teams?
3. Is there an effective training program within your company to train more managers or improve the leadership qualities to successfully work in such a distributed environment? If yes, then could you describe about those training programs?
4. Do you have any additional comments or items that you feel are important for our research team to consider? Do you have other contacts that could help us with more information for this research? E.g.: EPC or HVEC contacts.

APPENDIX F

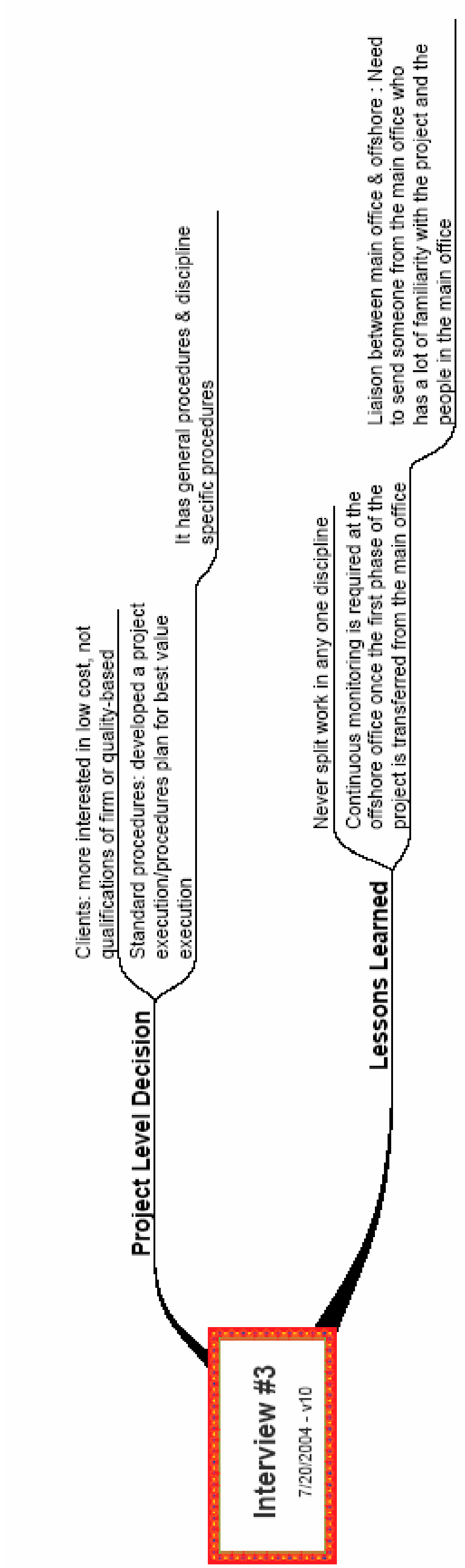
Sample Interview Content Analysis

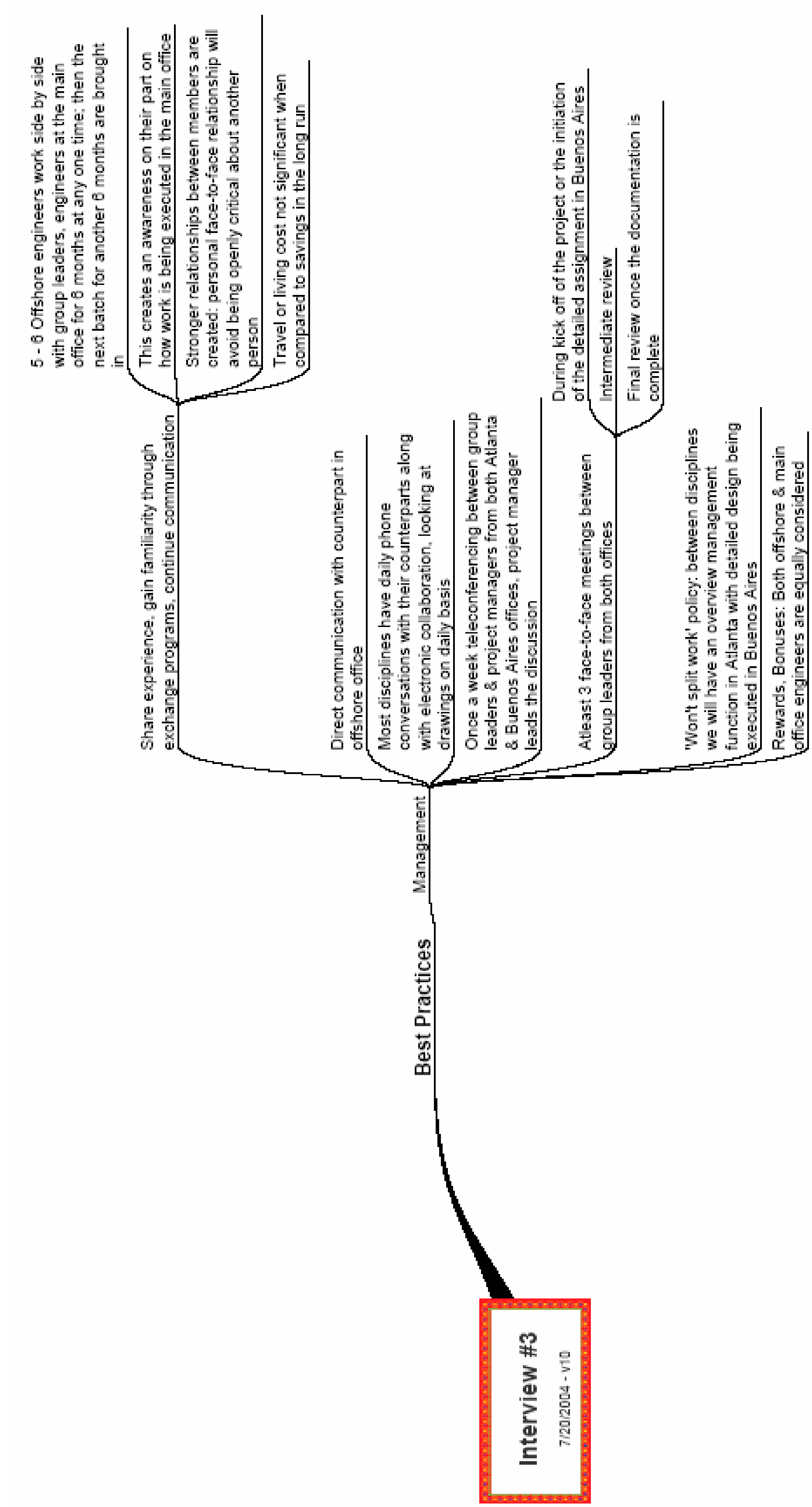

Interview #3
7/20/2004 - v10
Responsibilities
Drivers - 'Best Value Engineering Approach'
Organizational Level Decision
Project Level Decision
Lessons Learned
Best Practices

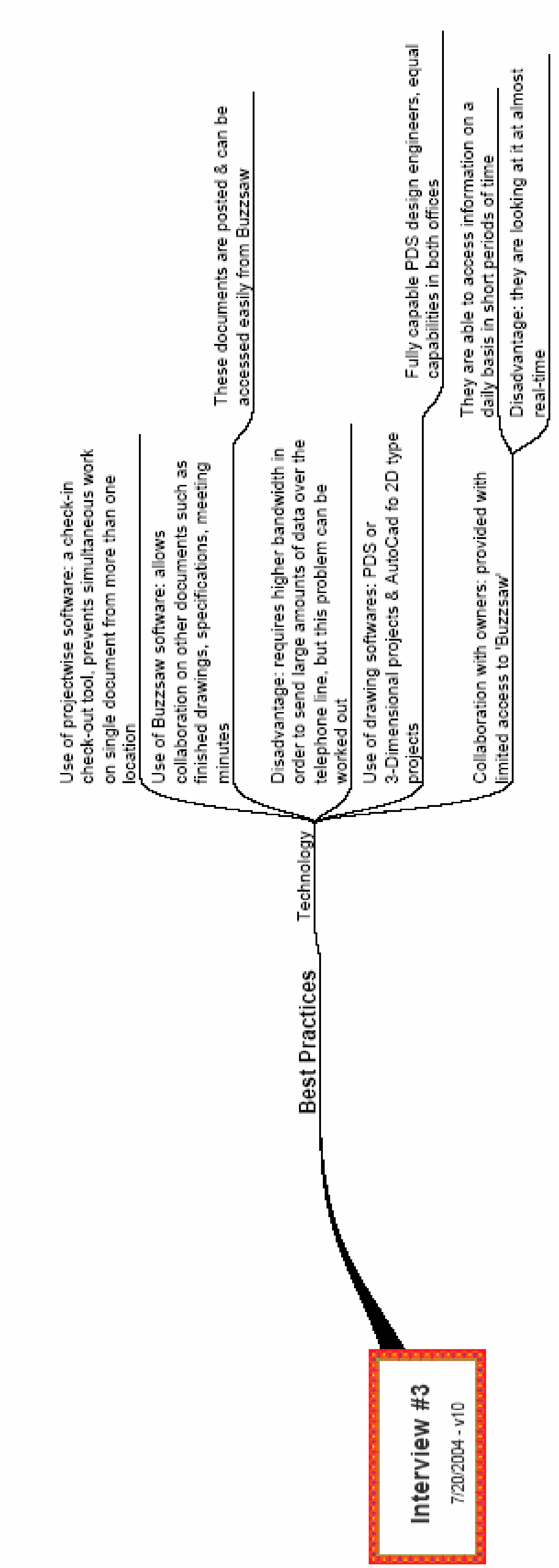

Interview #3
7/20/2004 - v10
Responsibilities
Coordination & execution of offshore engineering
Each department manager from various disciplines report directly
Drivers - 'Best Value Engineering Approach'
Financial reasons
Competitors use of offshore engineering capability



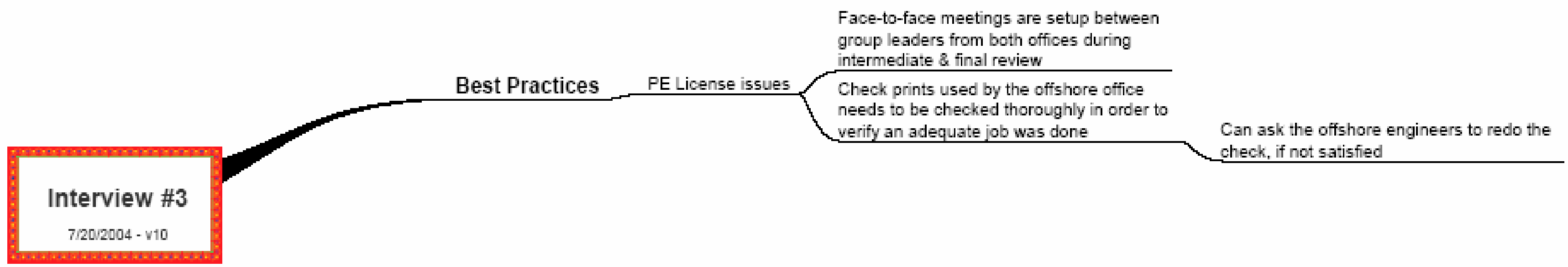
Interview #3
7/20/2004 - v10
Organizational Level Decision
Existing offices in Argentina, Brazil, & Mexico were bought from other owners in stages
Advantages: less time difference, no language problem, similar work ethics (very important for collaboration)
70% of work done offshore, Atlanta office provides conceptual design
Client schedule can influence on amount of work done in particular location
30% of work in US: group leader oversee, manage, answer questions, look at drawings
Mechanical discipline, process, equipment selection, specification, structural calculations still done in US
Negative reaction from domestic engineers
No escape: competition in present market demands 'lowest price'
Rates of offshore engineers: 1/4th of US engineers
Current trend in 'Best Value Engineering Approach'
At present 25%, but steadily increasing


Interview #3
7/20/2004 - v10
Project Level Decision
Clients: more interested in low cost, not qualifications of firm or quality-based
Standard procedures: developed a project execution/procedures plan for best value execution
It has general procedures & discipline specific procedures
Lessons Learned
Never split work in any one discipline
Continuous monitoring is required at the offshore office once the first phase of the project is transferred from the main office
Liaison between main office & offshore : Need to send someone from the main office who has a lot of familiarity with the project and the people in the main office


Interview #3
7/20/2004 - v10
Best Practices
Management
Share experience, gain familiarity through exchange programs, continue communication
5 - 6 Offshore engineers work side by side with group leaders, engineers at the main office for 6 months at any one time; then the next batch for another 6 months are brought in
This creates an awareness on their part on how work is being executed in the main office
Stronger relationships between members are created: personal face-to-face relationship will avoid being openly critical about another person
Travel or living cost not significant when compared to savings in the long run
Direct communication with counterpart in offshore office
Most disciplines have daily phone conversations with their counterparts along with electronic collaboration, looking at drawings on daily basis
Once a week teleconferencing between group leaders & project managers from both Atlanta & Buenos Aires offices, project manager leads the discussion
Atleast 3 face-to-face meetings between group leaders from both offices
During kick off of the project or the initiation of the detailed assignment in Buenos Aires
Intermediate review
Final review once the documentation is complete
'Won't split work' policy: between disciplines we will have an overview management function in Atlanta with detailed design being executed in Buenos Aires
Rewards, Bonuses: Both offshore & main office engineers are equally considered



Interview #3
7/20/2004 - v10
Best Practices
Technology
Use of projectwise software: a check-in check-out tool, prevents simultaneous work on single document from more than one location
Use of Buzzsaw software: allows collaboration on other documents such as finished drawings, specifications, meeting minutes
These documents are posted & can be accessed easily from Buzzsaw
Disadvantage: requires higher bandwidth in order to send large amounts of data over the telephone line, but this problem can be worked out
Use of drawing softwares: PDS or 3-Dimensional projects & AutoCad fo 2D type projects
Fully capable PDS design engineers, equal capabilities in both offices
Collaboration with owners: provided with limited access to 'Buzzsaw'
They are able to access information on a daily basis in short periods of time
Disadvantage: they are looking at it at almost real-time


Interview #3
7/20/2004 - v10
Best Practices
PE License issues
Face-to-face meetings are setup between group leaders from both offices during intermediate & final review
Check prints used by the offshore office needs to be checked thoroughly in order to verify an adequate job was done
Can ask the offshore engineers to redo the check, if not satisfied

APPENDIX G

Project Team Members

Project Team Members and their Companies

This appendix contains a list of the CII PT211 members who provided valuable help and guidance throughout the survey, interviews, and case study for this research. Without their support and integrity throughout the research process, this thesis would not exist. Due to confidentiality, some of the other participants' information can not be disclosed. But most of them had the following positions within their respective companies; President, Vice President, Director of Design, Senior Project Manager, Chief Technical Officer, Senior Project Engineer, Project Leader, Engineering Manager, Offshore Engineering Coordinator, Quality Assurance Director, Technology Director, and Engineering Director.

Mr. Robert J. Beaker - General Motors Corporation
Mr. Hector Brouwer de Koning - Black & Veatch
Mr. Dennis Chastain - Mustang Engineers & Constructors, L.P.
Mr. Chuan Chen - Pennsylvania State University
Mr. Gregory Gould - Burns & McDonnell
Mr. John Hackney - Nova Chemicals Corporation
Ms. Lona Hankins - ConocoPhillips
Mr. Robert E. Houghtaling - DuPont Engineering
Mr. Aivars E. Krumins - ABB Lummus Global
Mr. George Joseph - Pennsylvania State University
Dr. John I. Messner - Pennsylvania State University
Mr. James B. Mynaugh - Rohm and Haas Company
Mr. Batuk Patel - The Dow Chemical Co.
Mr. Matthew J. Petrizzo - Washington Group International
Mr. Reinhard Pratt - AMEC, Inc.
Mr. Gerald A. Schacht - Abbott Laboratories
Mr. Karl E. Seil - Stone & Webster, The Shaw Group Co.
Mr. Bruce A. Strupp - Parsons Corporation
Dr. H. Randolph Thomas - Pennsylvania State University
Mr. Todd White - Anheuser-Busch, Inc.

APPENDIX H

Human Subjects Approval

PENNSTATE

Vice President for Research
Office for Research Protections

The Pennsylvania State University
212 Kern Graduate Building
University Park, PA 16802-3301

(814) 865-1775
Fax: (814) 863-8699
www.research.psu.edu/orp/

Date: June 7, 2004

From: Mary B. Becker, IRB Administrator

To: George Joseph

Subject: Results of Review of Proposal - Exemption **(IRB #18812)**
Approval Expiration Date: June 6, 2005
"Effective Use of Global Engineering Work Force"

The Office for Research Protections (ORP) has reviewed and approved your application for the use of human participants in your research. By accepting this decision, you agree to obtain prior approval from the ORP for any changes to your study. Unanticipated participant events that are encountered during the conduct of this research must be reported in a timely fashion.

Enclosed is/are the dated, ORP-approved informed consent(s) to be used when enrolling participants for this research. Participants must receive a **copy** of the approved informed consent form to keep for their records.

The principal investigator is expected to maintain the original signed consent forms along with the research records for at least three (3) years after termination of ORP approval. The principal investigator must determine and adhere to additional requirements established by any outside sponsors.

If your study will extend beyond the above noted approval expiration date, the principal investigator must submit a completed Continuing Progress Report to the ORP to request renewed approval for this research.

On behalf of the ORP and the University, thank you for your efforts to conduct research in compliance with the federal regulations that have been established for the protection of human participants.

MBB/slk
Enclosure
cc: John I. Messner

Please Note: The ORP encourages you to subscribe to the ORP listserv for protocol and research-related information. Send a blank email to: L-ORP-Research-L-subscribe-request@lists.psu.edu <mailto:L-ORP-Research-L-subscribe-request@lists.psu.edu>.

Interview Consent Form

Effective Use of Global Engineering Work Force (IRB # 18812)

The Construction Industry Institute in collaboration with Penn State University is investigating the effective use of the global engineering work force. Our research team's goal is to develop a framework to address the comprehensive issues involved in establishing successful global virtual engineering teams through the identification of best practices in the utilization of personnel, work processes, tools and technologies. The intent of this interview is to gain a better understanding of the participant's views of the current status, tools, work processes, and driving factors for global virtual engineering teams and to collect information for further research regarding this topic.

Your participation in this study is completely voluntary and you may withdraw from the interview at any time or skip any questions, if you do not wish to answer. The interview will take approximately one hour and there are no perceived risks to your participation.

All the collected data will remain confidential. The information is solely collected for the purpose of research. Data that could be used to identify the individual source organization or person will not be communicated in any form to any party other than designated CII staff members and project team members who have signed the 'CII Survey Statement of Confidentiality' with the Construction Industry Institute.

If any recordings are made during the interview, it will be an audio or digital type of recording. The recordings will be stored in the Principal Investigator's locked office room. Only the Principal Investigator will have access to the recordings. All the recordings will be destroyed by the year 2008.

Participation in the interview implies consent to participate in the research. We may use direct quotes from the interview. But will definitely give you a copy to review before we publish.

If you have any questions, please contact John Messner or George Joseph at the address below.

Sincerely,

John I. Messner, Ph.D.
Assistant Professor of Architectural Engineering
The Pennsylvania State University
104 Engineering Unit A
University Park, PA 16802
Phone: 814-865-4578
jmessner@engr.psu.edu

George Joseph
MS Graduate Student
Department of Architectural Engineering
The Pennsylvania State University
104 Engineering Unit A
University Park, PA 16802
Phone: 814-865-3016
gxj131@psu.edu

For additional information concerning your rights as a participant, please contact the Office of Research Protection, 212 Kern Graduate Building, University Park, PA, 16802 or by phone at (814) 865-1775. This informed consent form was reviewed and approved by the Office for Research Protections at The Pennsylvania State University on (06/07/04 MBB). It will expire on (06/06/05 MBB).

Effective Use of the Global Engineering Work Force Survey

(IRB #18812)

Construction Industry Institute

Construction Industry Institute (CII)

CII PROJECT TEAM 211

The Pennsylvania State University

PENNSTATE

With advancements in technology and the globalization of economies, Virtual Teams (VT) have become a reality in the global engineering sector. The Construction Industry Institute in collaboration with Penn State University is investigating the effective use of the global engineering work force. Our research team's goal is to develop a framework to address the comprehensive issues involved in establishing successful global virtual engineering teams through the identification of best practices in the utilization of personnel, work processes, tools and technologies. For additional information, please go to the Project Description.

A *Global Virtual Team* is a group of geographically dispersed individuals organized through communication and information technologies that need to overcome space, time, functional, organizational, national, and cultural barriers for the completion of a specific task. For the purpose of this survey, please only consider Global Virtual Teams that contain members located in at least two countries.

Your participation in this study is completely voluntary and you may withdraw from the survey at any time or skip any questions, if you do not wish to answer. The survey will take approximately 10 - 15 minutes and there are no perceived risks to your participation.

All the collected data will remain confidential. Data that could be used to identify the individual source organization or person will not be communicated in any form to any party other than designated CII staff members and project team members who have signed the 'CII Survey Statement of Confidentiality' with the Construction Industry Institute.

We request your assistance with this study by completing an online survey. Please proceed to the appropriate survey by selecting either the Owner/Operator or EPC Organization survey below.

Go to Owner / Operator Survey	Go to EPC Organization Survey

Your confidentiality will be maintained to the degree permitted by the technology used. Specifically, no guarantee can be made regarding the interception of data sent via the internet by any third parties. Completion and return of the survey will be considered consent from the participant to participate in this study. Please print and keep a copy of this page for your records.

As the research progresses, we will update you with the latest results. Thank you for your cooperation. If you have any questions, please contact John Messner or George Joseph at the address below.

Sincerely,

John I. Messner, Ph.D.
Assistant Professor of Architectural Engineering
The Pennsylvania State University
104 Engineering Unit A,
University Park, PA 16802
Tel: 814-865-4578
jmessner@engr.psu.edu

George Joseph
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gxj131@psu.edu

For additional information concerning your rights as a participant, please contact the Office of Research Protection, 212 Kern Graduate Building, University Park, PA, 16802 or by phone at (814) 865-1775. This informed consent form was reviewed and approved by the Office for Research Protections at The Pennsylvania State University on (06/07/04 MBB). It will expire on (06/06/05 MBB).