

Virtual Teams: Guide to Successful Implementation

Paul S. Chinowsky, A.M.ASCE,¹ and Eddy M. Rojas, A.M.ASCE²

Abstract: The successful initiation and execution of a virtual team is gaining increasing attention in the design and construction community. From opportunities to integrate international and multidisciplinary teams to the opportunity to leverage the best resources in an organization on a given project, virtual teams can transform the concept of project planning and execution. However, potential barriers exist in several areas to the successful implementation of virtual teams. The needs of increased management emphasis, social and cultural understanding, and emphasis on common goals are only a few of the nontechnical factors that can turn successful virtual teaming into virtual frustration. When combined with traditional technical challenges including compatibility of systems, security, and the selection of appropriate technologies, the line between leveraging virtual technologies for enhanced solutions and introducing additional complications into the project process is one that can be easily crossed. This paper presents the findings of research that addresses the opportunities and potential barriers to successful virtual teams in the engineering, procurement, and construction industry. Combining results from current research, industry practices, and early results from nonconstruction industries, the research findings provide an initial path to successful virtual team implementation.

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Introduction

Virtual teams are receiving increasing attention within the construction industry. As companies and projects increasingly utilize multinational, interdisciplinary, and multiorganizational partnerships, the need for greater and more efficient communication alternatives is also increasing. However, little guidance currently exists to assist in the successful implementation and management of these teams. In an effort to fill this information gap, the Construction Industry Institute (CII) embarked on a study focusing on making virtual teams work in the engineering, procurement, and construction (EPC) industry. The scope of this effort included the examination of current research on the topic, a study of current virtual team practices within the industry, the study of cases outside the EPC industry, and the development of recommendations for successfully implementing virtual teams in the EPC industry. This paper presents the critical findings from this research effort, emphasizing the managerial and technological guidelines developed to successfully implement virtual teams in the construction and engineering industries.

The management and technology issues and recommendations presented in the following sections represent a combination of experiential knowledge, empirical study, and compilations from

existing research. In terms of the experiential knowledge, virtual team implementations have been a focus of academic study by the writers for over six years (Chinowsky 1999), including levels of study that ranged from small groups to international student collaborations incorporating seven countries and 11 universities. Additionally, experiential knowledge was employed by the team through industry experience by research team members. Application experience from companies including Texaco, Parsons Engineering, and BP-Amoco represents many years of implementation effort in the virtual teaming domain at many stages of virtual team technology development.

Based on this diversity of virtual team experience, an initial requirement in the research was to provide a common foundation for the discussion of virtual teams. Specifically, a common definition was required that defined what virtual teaming actually encompasses in the construction context both today and in the future. As organizations discover when approaching the topic of virtual teams, the first barrier to successful implementation is the lack of such an accepted definition. Therefore, to assist in the pursuit of this topic, the following virtual team definition was developed based on a combination of work conducted by the writers as well as input from previous research, as discussed in the next section: “A virtual team is a group of people with complementary competencies executing simultaneous, collaborative work processes through electronic media without regard to geographic location.”

The central concept in this definition is that virtual teams do not refer to traditional work sharing, electronic communications, or other forms of dividing projects that require individuals or groups to work independently. Rather, virtual teams allow individuals or groups to collaborate on a project in real time through electronic media. In this manner, the virtual team operates as an integrated team whose members may happen to be located in different parts of the country or world. The potential advantages of this type of collaboration are numerous, including efficiency of project execution, removal of physical boundaries, the integration and optimization of competencies, and the ability to form new

¹Associate Professor, Dept. of Civil and Environmental Engineering, Georgia Institute of Technology, 790 Atlantic Dr., Atlanta, GA 30332-0355. E-mail: paul.chinowsky@ce.gatech.edu

²Assistant Professor, Dept. of Construction Management, Univ. of Washington, 116 Architecture Hall, Seattle, WA 98195-1610. E-mail: er@u.washington.edu

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partnerships. Although disagreement exists on the inclusion of all aspects of this definition, it is the research team's belief that the future of virtual teaming is captured in real-time collaboration and simultaneous work processes. The validation of this hypothesis must be left for reflection at some point after virtual teams have become standard business practice.

The promise of virtual team advantages prompted the development of the management and technical guidelines for virtual teams presented in this paper. Arriving at these guidelines required input from two distinct sources—previous research and current practices. In response to the former, literature reviews were conducted to develop a context of virtual teaming for the construction industry. Specifically, the development of virtual teaming, the current use of virtual teaming, and the ramifications of the technology were examined to produce a foundation on which to study current virtual team implementations within the industry. Once this foundation was developed, the writers addressed the issue of current practices by surveying CII members to obtain a picture of virtual team practices within the construction industry at the current time and for the near-term future. Finally, interviews were conducted with CII members, outside industries, and technology providers to obtain initial lessons learned for successful virtual team implementation. The result of this combination is that the basis of the issues relies in some cases on significant experiential evidence. This experience may not always be supported by extensive literature, but it is supported in each guideline by multiple company experiences and adopted practices.

The combination of the selected data sources therefore provides the background for the development of the management and technical issues presented in this paper. Although the issues may not address every eventuality that may be encountered in an individual project or organization, the issues are fundamental in their applicability to successful virtual team implementation and must be addressed to avoid creating technical or managerial roadblocks for virtual teams.

Context

The decision to introduce virtual teaming into the EPC organization may appear on the surface to be insignificant. If the technology appears ready and a potential team has demonstrated an above average ability to coordinate and produce solutions within the given constraints, then an organization may assume that a virtual team is a logical next step in project coordination. However, these surface characteristics are only the beginning of a larger set of considerations that must be made prior to implementing a virtual team environment. Specifically, the decision to incorporate virtual teams should not be made without an understanding of the specific definition of a virtual team, an understanding of previous results from the technology, and the potential impact of successfully implementing virtual teams.

Definition

As illustrated in Table 1, virtual teams represent one end of an electronic interaction spectrum. To assist in the definition of virtual team efforts and the classification of existing communication and collaboration technologies, the research team established this interaction spectrum. The fundamental reason for this spectrum is to reinforce the virtual team definition. Specifically, any communication technology can be argued to be a virtual team technol-

Table 1. Spectrum of Electronic Interaction Technologies as Divided into Three Primary Collaboration Categories for This Research

Spectrum category	Interaction technology	Description
Communication	Phone/teleconferencing	Traditional analog, oral communication
	Fax	Digital or analog text communication
	E-mail	Digital text communication
Cooperation	Project Web sites	Digital repository for project data and communications
	Discussion board	Electronic message center for archiving text communication
	Work sharing	Asynchronous data exchange and project solution process
Collaboration	Videoconferencing with data sharing	Synchronous discussion with ability to exchange project information
	Virtual teaming	Real-time data manipulation and exchange

ogy. Phone conversations, e-mail, and faxes all have virtual team attributes, but all fail to meet the definition established in this research effort. Therefore, to assist individuals in the understanding of virtual teams and to restrict the virtual team focus to the previously stated definition, the following categories of interaction technologies are presented.

Communication Technologies

The first level of interaction technologies is the group comprising communication technologies. These technologies, while still central to the function of team interaction today, are based on an age-old concept of providing another individual with a message that communicates a thought regarding the current issue under discussion. These messages can be asynchronous, such as in the case of e-mail and fax technologies, or synchronous, as in the case of telephone conversations or teleconferencing. In either case, the underlying similarity between the technologies is the sole focus on message communication. No data outside of those contained in the message itself are transmitted, and no manipulation of the project solution is accomplished directly. Rather, the message transfers a thought or action concerning the project solution, thus requiring the recipient of the message to implement the change or suggestion to the actual project documents. The limit of these technologies is defined by their focus on communicating thoughts rather than manipulating project data. Communication technologies thus fail to meet the virtual teaming definition employed in this project, by failing to allow synchronous manipulation of project data.

Cooperation Technologies

The second level of interaction technologies is the group comprising cooperation technologies. These technologies are an electronic advance over the previous category and represent introductions to the construction and engineering industry over the last decade as computing technologies have similarly increased in power and presence. The central focus of these technologies is the ability for a group of individuals to asynchronously interact and

manipulate project data. In this category, individuals may access a central project Web site to exchange project documents, exchange information on specific project components through central databases (work sharing), or develop an ongoing discussion of specific project concerns that incorporates project document revisions (discussion boards). In these cases, project participants are accessing original project data, but do not have the ability to manipulate the data in a shared, real-time experience. Once again, these technologies fail to meet the virtual teaming standard by restricting information manipulation to asynchronous access, manipulation, and posting.

Collaboration Technologies

The final level of interaction technologies is the group comprising collaboration technologies. It is in this group that virtual teaming is located, at the end of the interaction spectrum. In contrast to the preceding cooperation technologies, collaboration technologies are characterized by their capability to permit synchronous, real-time manipulation of common project data. Specifically, the teams that incorporate an electronic collaboration focus have the ability to synchronously access and manipulate project data from a central location. In the optimum scenario, project participants have the capability to visually and orally communicate, in addition to the shared data exchange and manipulation capability. In this sense, project participants are re-creating an electronic meeting space that allows participants to experience the complete range of human interaction that occurs during collaboration on a project, with the exception of physical interaction.

The definition of these three categories provides the foundation for the current research effort. The current focus is restricted to analyzing the potential impact, barriers, and requirements for technologies in the final interaction category. The results in this paper have been developed to successfully introduce this technology into project teams. The recommendations are not intended to enhance or modify interactions that routinely encompass the communication and cooperation technologies.

Background

The introduction of virtual teaming as an interaction technology and workspace innovator has been addressed by management and computer science researchers for over a decade. Early work on the management impact of virtual teams discussed the impact on trust, organization form, and organization process (Miles and Snow 1986; Gersick 1988; Davidow and Malone 1992). These studies highlighted the distinct differences between virtual teams and traditional colocated project teams. Of particular interest to these writers was the need to alter traditional management styles to accommodate off-site project members (O'Hara-Devereaux and Johansen 1994). These researchers quickly identified that communication between distributed teams is characterized by distinctively different patterns than those demonstrated in traditional teams. Issues such as trust, social interaction, and group performance moved to the forefront of concern as organizations struggled to adapt to the introduction of virtual teams as integral components of the organizational process (Straus and McGrath 1994).

The progression of this research provides a foundation for the development of introduction guidelines into the construction and engineering industries. As recognized in continued virtual team research, the issues of communication exchange and interpretation require significant analysis prior to the final introduction of a technical interaction solution (Walther and Burgoon 1992). The

development of guidelines and warnings for organizations attempting to implement virtual teams is a common thread in virtual team research over the last decade (Pape 1996; Maruca 1998; Wardell 1998; Wenger and Snyder 2000). In each case, the research demonstrates that managerial issues require equal attention to the technical implementation questions addressed by the organization.

However, the technical component of virtual team implementation was not overlooked by researchers developing a foundation for this new form of organizational interaction. Rather, issues such as interface interaction, security, and transfer rates proved to be stumbling blocks requiring attention before this technology could achieve its intended impact (Romano et al. 1998; Igarria et al. 1999; Yager 1999). The technical solutions to these issues are now evident in the increase in standardization between network architectures, the enhancement of network and Internet interfaces to permit greater production by users, and the increased stability of wide area networks to permit virtual teams to eliminate the physical boundaries that are the distinguishing feature of traditional project teams.

The combination of the management and technology research contributing to the virtual team evolution has been incorporated in several industries. The manufacturing industry in particular has embraced the virtual teaming concept. Highlighted by notable success stories such as those by Boeing on the 777 aircraft project in the aerospace manufacturing industry, virtual teams are now receiving extensive examination by such organizations (Holusha 1991). These early implementers are setting the path for the introduction of similar technologies into the construction and civil engineering industries. The guidelines in the following sections reflect this diverse foundation and extend the concepts to the specifics of distributed project teams in the civil engineering context.

Impact

As businesses continue to find that they must compete in a fast-paced global market place, the need to team in a virtual environment becomes more evident and imperative. Product innovation, development, and production can no longer be accomplished in a single conference room, if it is to be an accepted and a profitable product.

The engineering, procurement, and construction community has been working toward a virtual project execution environment for a number of years, with early approaches utilizing a work transfer to what were called low cost engineering centers (LCEC). This effort entailed performing the initial engineering and preliminary design in a centralized domestic engineering office, and subsequently transferring the entire design package for a facility to an LCEC for execution of the detailed engineering and design. The primary purpose of this effort was to reduce the cost of the engineering component of project execution. This work splitting effort has gradually been moving toward a work sharing effort, whereby the design has an element of interaction, but the concept of teaming is still not a reality on these projects.

The impact of the virtual team concept on the EPC community is the ability to move beyond the work sharing concept and develop a true interactive arrangement with all project participants. This shift in the execution model for both owner and EPC organizations will fundamentally alter the way that EPC projects are executed (Lipnack and Stamps 1997). The impact of virtual teaming will not be isolated to the development of technical solutions; rather, virtual teaming will impact the fundamental concepts of how EPC projects are initiated, executed, and delivered, as well

as how EPC-owner relationships are maintained over extended periods of time.

Management Issues in Virtual Teaming

The introduction of virtual team technologies may be viewed by many individuals and organizations as a technical implementation that is similar to introducing new software or hardware into the company. In fact, virtual teaming requires a combination of successful technical and managerial responses to ensure that the potential for success exists. A lack of attention to either of these categories will result in frustration, cost overruns, and, ultimately, the failure to produce a successful project solution.

This section outlines the 10 management issues that must be addressed when initiating and maintaining virtual teams. As discussed previously, researchers have found that the breadth of these issues reflects the broad impact that managerial issues have on the virtual team process. As discovered by companies initially testing these technologies, virtual teams may fail if technology concerns are not appropriately addressed, but success will only occur if appropriate management challenges are addressed throughout the project (Gould 1997; Olson and Olson 2000).

Developing a "Team"

A group of individuals, whether located in a single office or distributed globally, retain a basic need to develop social relationships. Humans are social animals and desire the development of friendships, acquaintances, and interactions in all aspects of their lives. This fact lies at the center of the most frequent cause of virtual team failures. Although virtual teams allow distributed groups to complete tasks while remaining geographically separated, the need for these teams to establish initial relationships cannot be overlooked (Pawar and Sharifi 1997). Specifically, virtual teams require initial face-to-face meetings to develop a sense of "team" for their members.

Reinforcing Project Objectives

One advantage of a virtual team is that each member can work independently toward achieving a common goal. Unfortunately, this advantage is also a potential hazard for virtual teams. Individuals working on a specific part of a project, separated geographically from other members of the team, may misinterpret, inadvertently change, or lose focus on the overall goals and objectives of the project. Whereas a team that is meeting regularly, both formally and informally, will restate and reinforce objectives, a virtual team member may lose this reinforcement in between formal virtual meetings. Therefore, a primary task for virtual team managers must be the frequent restatement of goals to the team to ensure that every member remains focused on the common objectives and goals.

Visiting Remote Participants

Virtual teams and traditional teams are dependent on every member completing his/her assigned task in an efficient and effective manner. However, where this dependency diverges is in the maintenance of the team progress. Whereas a manager in a traditional team can provide one-on-one feedback to individuals who are performing above or below expectations, this feedback can be difficult in a virtual environment. Both praise and rebuke can be misinterpreted or exaggerated when delivered via e-mail, telecon-

ference, or videoconference. Therefore, virtual team managers must personally visit each individual on the team during the course of the project to deliver evaluations and retain the relationship established during project initiation.

Team Trust

The element of trust is significant in an EPC project. The multiple constituencies and participants in the project, the size and complexity of the project, and the distributed nature of the participants are only a few of the issues that make EPC projects difficult for the project manager. This difficulty can often be exaggerated if members of the team have not established a trust-based relationship (Latane et al. 1995; Lewicki and Bunker 1995; Jarvenpaa and Leidner 1998; Gundry 2000). This situation can be exacerbated in a virtual environment. When individuals are separated, they are less likely to establish the one-to-one relationships upon which trust is often built. Therefore, the communication by management of the project status and the role each member is playing in delivering a final solution must be continued throughout the project to ensure that each member understands the relative roles and responsibilities.

Conflict Resolution

Building on the trust issue, the elimination or reduction of regular face-to-face meetings can lead to a perception by team members that greater formality must be established in communications than that found in traditional teams. This formality is often translated into increased e-mails, an increase in the number of individuals copied on e-mails, an increase in formal memos, or increases in the number of faxed confirmations of e-mails. In these scenarios, small disagreements can escalate quickly. However, in most cases, this escalation can be avoided if conflict resolution procedures are established early in the team building process, or if sensitive questions in areas such as design are handled through traditional methods such as phone calls. Virtual communication may not always be the appropriate communication mechanism.

Electronic Discussions

Every team contains both individuals who are more likely to dominate discussions in face-to-face meetings, extroverts, and individuals who are more likely to remain quiet through the meetings introverts. In traditional meeting circumstances, these roles often result in solutions being driven by the extroverts, with input from introverts occurring only when these individuals believe it is essential to their project component. Translated, this process often results in a narrow number of solutions being investigated, with the goal being to complete the meeting and meet the next objective. In a virtual team environment, this process adds an additional component, electronic communication. Although the interactive sessions may resemble the traditional face-to-face sessions, the virtual team is more likely to continue discussions after a meeting due to the ease of injecting electronic comments into the postmeeting scenario (Chinowsky 1999). In this manner, individuals who feel more comfortable making comments by e-mail rather than in a traditional meeting setting may elect to wait until after the meeting to state ideas to the team. These responses may result in the decisions made in the earlier meeting being rejected and a new set of decisions being developed. From a manager's perspective, this continuation can be very costly to both the budget and the schedule. Once again, the need for oversight and

initial guidelines for meetings and discussions becomes apparent, as the traditional controls associated with limited meeting times are dissolved in a virtual environment.

Team Member Expectations

Project teams require clear directions as well as clear expectations for each member or subgroup. The lack of these clear expectations can result in partial solutions that do not mesh together in the final, comprehensive project solution. This fact is true in any team environment. However, virtual team environments amplify this issue. In virtual environments, individuals lose the informal oversight that is provided through ad hoc meetings with other team members. The loss of these informal discussions results in the individuals being tasked with a greater responsibility to retain a focus on their expected outcomes and objectives. Therefore, to assist these individuals in retaining this focus, managers must be as clear as possible during the start of the project regarding what the expectations will be of each team member during each stage of the project.

Team Leaders

In traditional teams, management skills focus heavily on meeting management, resource planning, and personal communications. In virtual team environments, these skills remain important, but the personal communications aspect gains increasing importance based on issues previously discussed in this section. The impact of these skills is directly relevant to the selection of project managers in virtual team environments. To increase the likelihood of success, leaders should be chosen based on increased attention to their ability to communicate and develop relationships with team members. In the virtual environment, these leaders will respond to the demands placed on virtual teams significantly better than leaders who rely on traditional technical skills to pursue successful solutions.

Workload Increases

An undeniable fact of virtual teaming is that the amount of electronic communications will increase for every member of the team. The lack of informal communication opportunities results in a commensurate reduction in opportunities to informally discuss solutions to the current project. To make up for these lost opportunities, team members will increase their electronic communications in an effort to obtain critical feedback and input into their problem-solving processes. The side effect of this process is an increase in the demand for individuals to formally respond to electronic inquiries, memos, or formal reviews. If a team does not institute initial guidelines for these communications, such as who should be copied on messages, when it is appropriate to send formal messages, and when the phone is a more appropriate form of communication, team members will increase the risk of exponential communication growth.

Team Training

The introduction of virtual team technologies will highlight the fact that not every member will feel equally comfortable with the technology. Similarly, differing workloads will prevent each person from remaining equally current on every piece of technology being used in the virtual environment. This is a reality that exists in every organization, regardless of size or function. Given this

fact, every organization must commit to providing each member of a virtual team with equal training. Every member must be required to attend training sessions to remain current on each piece of software being used in his or her virtual environment. It is only through this regimen of training and continuous learning that virtual teams can remain focused on generating project solutions. The 10 previous guidelines are summarized as follows:

1. Team issues
 - Virtual teaming requires initial face-to-face meetings to develop a sense of “team.”
 - Managers must visit remote participants during the course of the project.
 - Trust between team members is difficult to establish when operating in a virtual environment.
 - Virtual team leaders should be selected with an acknowledgment of the unique demands placed on distributed teams.
2. Process issues
 - The project objectives must be restated and reinforced frequently to ensure that all members remain focused on a common outcome.
 - Conflicts must be addressed quickly to prevent unresolved issues from interfering with communications.
 - Discussions on decisions will be more difficult to contain as participants continue discussions via electronic media.
 - Expectations of each team member must be stated clearly to assist the members as they work independently.
 - Team member workloads should be monitored to ensure that significant increases do not occur due to increased electronic communications.
 - Regular training must occur equally for all members of the virtual team.

Technology Issues in Virtual Teaming

Complementing the management issues addressed in the previous section, this section focuses on three technology components that lie at the center of virtual teaming—collaboration tools, security, and standards. Although each of these areas has solutions already developed to support virtual teams, the range of solutions available to organizations can make technology confusing and expensive. As stated earlier, technology will not guarantee the success of a virtual team, but it can cause the failure of the team. Therefore, any organization embarking on a virtual team effort must develop practice statements that reflect operating positions in regard to the following three technology areas.

Collaboration Tools

Virtual teams rely on a variety of information technologies to perform collaborative work. These technologies can be classified in three major areas—information management, conferencing, and project management. The selection of the tools within each group that will combine to form the virtual team environment is the first component of the technology practice triad.

Information management technologies help virtual team members to exchange and manage data. These tools support the most basic level of collaborative work. Some of the data exchange tools in this category include e-mail, file transfer protocol (FTP), portable document format (PDF), and a variety of application viewers. These tools are popular because they support asynchronous communications. Data management tools, on the other hand, require enterprise support. Some examples of data management

tools include document management systems, database management systems, and workflow automation tools. Document management systems support the organization, distribution, and access of documents across an organization. Despite the obvious advantages of data management tools, they do not necessarily perform well in a virtual team environment when members from different organizations must share data, as each organization may support different applications and interoperability problems may arise.

Conferencing technologies help virtual team members to meet in virtual environments and exchange ideas and information in real time. Some examples of conferencing tools include chat rooms, instant messaging systems, whiteboards, and audio and video conferencing. It is common for off-the-shelf software applications to support several of these tools under a common environment. Even though these tools work well during informal gatherings, the lack of tracking documentation makes their implementation difficult for formal meetings.

Project management technologies help virtual team members create their own collaborative environments. They have been designed with the objective of overcoming the problems encountered by information management and conferencing technologies such as interoperability limitations and the lack of documentation to be traced. These technologies usually integrate a variety of tools in a unified environment when they may support e-mail, FTP, PDF, application viewers, document management, data management, work flow automation, instant messaging, chat rooms, whiteboards, and audio and video conferencing.

Security

An important objective of virtual teams is to create a reliable environment where teams can exchange information in a secure manner. In the process of sharing and/or exchanging information, the transmission of documents is an issue and its success depends on the capacity of the transmission medium and the security it may have. Therefore, the second component of the technology triad for virtual teams is the identification of a security process that meets the needs of each virtual team participant.

Recipients and senders of electronic documents need to verify that the information transferred during a project is reliably being communicated and is secure in its transmission. Several techniques exist to accomplish this task, with each providing a different level of security for the user. Fundamentally, this verification process is done through a process known as authentication. Authentication techniques are classified as secret-key cryptography systems and public-key cryptography systems. In general, cryptography systems use an algorithm to convert plain text into an encrypted block of illegible text.

In addition to guaranteeing that the information received came from the intended sender, it is also essential to make sure that the information shared and/or exchanged electronically will not be read by anybody who is not allowed to do that. Encryption provides this security for virtual teams by transforming messages in order to make them legible only for the intended recipients. The combination of these authentication and encryption techniques guarantees the secure transmission of electronic information within a virtual team environment. Finally, after securing the transmission of information and authenticating the participants, the next step for the implementation of a secure virtual team environment is to guarantee secure connectivity. The technology that makes this secure connectivity possible is known as virtual private networks (VPNs).

The term virtual private network refers to a combination of technologies and techniques that secure the communications between two end points by setting up a secure communication tunnel incapable of being penetrated. By the creation of this tunnel through the Internet or some other public network, VPN technology provides the same level of communication security as that provided by private organization networks or intranets.

Interoperability and Standards

Interoperability is the ability of a system or a product to work with other systems or products without special effort on the part of the customer. Assurance of effective interoperability requires not only the use of compatible software and hardware, but also changes in how organizations work and in their attitudes toward information. Therefore, the final component of the technology triad is the establishment of interoperability standards that control the exchange of information within the team. To better understand this concept, interoperability can be classified as follows:

- *Technical interoperability.* This guarantees communication and information exchange, storage, and retrieval between components of a network.
- *Semantic interoperability.* This ensures that systems and products understand words that describe similar concepts, or identical terms that mean very different things.
- *Political/human interoperability.* Process change, and extensive staff and user training are important to ensure the effective long-term use of any service.
- *Intercommunity interoperability.* This refers to the ability to find and retrieve information from community institutions such as national and local government, public libraries, museums, archives, and so on.
- *International interoperability.* Each of the issues mentioned previously may be magnified when considered on an international scale, where differences in technical approaches, working practices, and organization differ greatly from one country to another.

Standards exist for programming languages, operating systems, data formats, communications protocols, and electrical interfaces. From the perspective of a virtual team, standards are extremely important because they allow the combination of products from different manufacturers to create a properly functioning system.

The technology guidelines are summarized as follows:

1. Appropriate technologies
 - Selection of collaboration tools must be made to establish an integrated virtual environment.
 - Project management tools must support the virtual environment and the project process.
2. Security
 - Documents must be secured before, during, and after transmission to ensure the integrity of the information.
 - Participants must be authenticated to ensure that information is distributed between project participants.
 - Secure transmission tunnels must be established if secure information is being transmitted within the virtual team environment.
3. Interoperability and standards
 - Interoperability of software must be established prior to inclusion within the virtual team environment.

Table 2. Overall Statistics from Industry Study on Current and Future of Virtual Team Technologies

Question focus	Options	Answer percentage
Current use of virtual technologies	Integral part of all projects	13
	Use on some projects	39
	Use of first projects	3
	Testing	19
	Not using	26
Part of the project currently using VT	Predesign	31
	Design	36
	Construction	22
	Start-up	11
Five-year projected use of VT	Decrease	0
	Marginal increase	7
	Considerable increase	35
	Routine business	58

- The virtual team and environment must address the spectrum of interoperability definitions that are appropriate to the given project.

Industry Practices

The development of the previous guidelines provides an entry point for organizations within the EPC industry to successfully implement virtual teaming technologies. This entry point is required, due to the finding that the implementation of virtual teams is still in its infancy within the EPC industry. As evidenced by data collected by the researchers, there is significant interest in the topic, but there is still a long way to go to reach full implementation. To reach this conclusion, the researchers embarked on a data collection phase to determine the current virtual teaming practices within a segment of the industry. In this process, the research team delivered surveys to 94 companies affiliated with the Construction Industry Institute (CII). The surveys focused on four distinct components—current application of virtual team technology, expected future use of the technologies, managerial issues related to virtual team implementation, and technology issues related to virtual team implementation. The latter two sections reflected the guidelines presented in the previous sections by asking whether the respondents were addressing these issues in their current or anticipated implementation of virtual teams.

The research team received 31 responses to the survey, a 33% return rate, which the researchers considered an adequate statistical representation of the surveyed population. Within the survey sample, 65% of the responses were from EPC owners and 35% were from EPC contractors. Each of the individual respondents was responsible for making or overseeing virtual team decisions within his or her organization.

The results from the survey effort provide a snapshot of current virtual teaming practices within the EPC industry, as they reflect the implementation guidelines developed within this study. As illustrated in Table 2, the current use and anticipated use of virtual teaming differ significantly within the organizations. Of the 31 respondents, 45% had never used virtual teaming or were in initial testing phases. Only 20% of the companies used the technology on all projects. In contrast, 58% of the companies believe that virtual teaming will be routine business within the

Table 3. Industry Statistics on Current Virtual Team Practice in Reference to Management Issues

Question focus	Options	Answer percentage
Virtual team impact on feeling of “team”	No impact	3
	Less like an integrated team	28
	More like a part of the team	24
	Did not study the issue	45
Impact on member participation	More comfortable in VT environment	14
	Less communicative in VT environment	14
	No difference	14
	Did not study the issue	58
Impact on trust	More trust	7
	Less trust	18
	No real difference	21
	Did not study the issue	54
Impact on leader development	Same people become team leaders	19
	Different groups or types become team leaders	16
	Did not study the issue	65

next five years, while the rest (42%) believe that the use of virtual teaming will increase considerably in the same period.

The second set of data summaries, the management data, is illustrated in Table 3. In this section of the survey, the researchers were focused on determining the degree of awareness and active pursuit the organizations were undertaking to address the management issues associated with successful virtual teams. In this category, the primary focus is on the number of organizations that are not studying management related issues, but have stated that they will be actively introducing virtual team technologies in the next five years. As summarized in Table 3, 45% or more of the organizations have not studied issues related to the “team” feeling, solution process impact, establishing trust, or selecting team leaders. However, these same organizations have recognized the greater difficulty in engaging team members in the solution process and in managing distributed teams. Therefore, the data illustrate that indicators have been identified by organizations that suggest a difficulty with the management of virtual teams, but these same organizations have not identified the underlying issues highlighted in this research effort.

The final set of data summaries, the technology data, is illustrated in Table 4. Similar to the management data, this segment of the survey captured the impact that technical issues were playing in the advance of or hindrance to virtual team implementation. From this perspective, security is the overwhelming concern of organizations implementing virtual team technologies, with 68% of the organizations identifying this factor as a precluding step to full implementation. In contrast, the research found that only 36% of the organizations identified compatibility as a primary barrier to virtual teaming. This result indicates that organizations are adopting either standard procedures or common software to minimize the difficulty of transferring documents between organizations and organization personnel. Finally, it is interesting to note that one in five companies (22%) indicated that they are not currently engaging in any electronic collaboration with other companies. This statistic follows the anecdotal evidence collected by the researchers that organizations may be willing to implement virtual

Table 4. Industry Statistics on Current Virtual Team Practice in Reference to Technology Issues

Question focus	Options	Answer percentage
Security concerns precluding full advantage of collaboration tools	Yes	68
	No	32
Concern with interoperability issues	Compatibility issues a major problem	36
	Concerned, but have not experienced major problems	57
	Not concerned with issue	7
VT problems due to firewalls	Do not engage in collaboration with outside organizations	22
	Do not have firewalls	0
	No problems with firewalls	15
	Not using the tools because of problems	22
	Problems have been solved	41
Use of electronic document approval	Yes	42
	No	58

teaming internally, but teaming with other organizations raises significant security, legal, and interoperability concerns that must be solved prior to a commitment to engage in cross-organization virtual teaming.

As illustrated by these data, there is a diverse spectrum of implementation stages for organizations within the EPC industry. However, the agreement that this technology will be a central component of business within the next five years is a strong indicator that the organizations must move rapidly toward a goal of implementation. Additionally, if they are to meet the five-year projection, adequate attention must also be placed on addressing the combination of management and technology issues associated with virtual teaming technologies.

Conclusions

The successful implementation of a virtual team requires an organization to address issues from a diverse set of influences. Managerial and technical issues both require serious analysis to provide the foundation for successful virtual teams. However, the research summarized in this paper provides four general lessons for any EPC organization considering the use of virtual teams in the solution generation process.

Modify Processes

The use of virtual teaming impacts technical and managerial processes within an organization. However, rather than responding to these impacts by altering existing processes to accommodate remote collaboration, successful virtual teams require work processes and organizational structures to be reexamined and restructured with a specific focus on distributed virtual teams.

Focus on the Big Picture

The emphasis of any project should be on the overall completion of the project. Unfortunately, this focus can lead to an overem-

phasis on tasks and a loss of perspective on the big picture. To remedy this situation, successful virtual team implementations require a constant emphasis on the big picture goals and objectives. An overemphasis on task distribution for distributed team members will result in the team losing the big picture perspective and failing to achieve an overall solution that meets all project objectives.

Protocols and Standards

As repeated several times in this paper, technology will not guarantee the success of a virtual team, but it may lead directly to the failure of such a team. Of particular importance in this regard is the need to establish data sharing protocols and standards prior to the start of a project. Since data stand at the center of any solution generation process, a formal set of standards and procedures should be set by the organization and introduced to the team as part of the project initiation function.

Empower Teams

The empowerment of teams to make independent decisions related to the project and perhaps the business is an essential component of reinforcing the team concept. As stated previously, this focus on the big picture is an underlying requirement for successful virtual team implementation. Teams receiving the greatest independence and opportunity to make overall project decisions will function as better teams and reduce the likelihood that geographic separation will affect the project outcome.

Addressing these fundamental components will provide an organization with a starting point from which to successfully implement virtual team concepts. Building on this start to achieve enhanced project results requires constant management oversight and technical training. However, the organization that is able to implement these changes has the opportunity to gain advantages by applying the best resources to the appropriate project.

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