Critical Communications Variables

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Abstract: Effective communications are essential to the successful completion of engineering, procurement, and construction (EPC) projects. Research from the Construction Industry Institute (CII) confirms this hypothesis. However, this finding would be of little benefit without a means for measuring a project's communications effectiveness. This paper documents the efforts of a CII research team in identifying and measuring critical communications variables during the execution phases of EPC projects. It confirms the common recognition of communication problems, provides insight into communications theory, and outlines procedures used by the research team throughout the study. Critical communications variables identified in the process are consolidated into six manageable categories establishing the basis for a communications improvement program. These categories in relative order of importance are accuracy, procedures, barriers, understanding, timeliness, and completeness. The paper concludes by acknowledging that this is the first step in solving project communications problems. To gain maximum benefit from this research, the categories and variables identified must be incorporated into an assessment tool and applied as part of a communications improvement program.

INTRODUCTION

Today's projects are technically complex and schedule driven. Their multidisciplinary nature requires management and execution by highly skilled, task organized project teams whose members are drawn from both owner and contractor organizations. Throughout a project, relevant information must be identified and disseminated among team members. Project performance can be enhanced through the implementation of effective project communications and conversely, projects can fail if hindered by poor communications. Thus, project team communications is one of the major challenges to a project's success.

Although studies have highlighted the importance of effective communications for project success, there has been little effort to measure reliably communications effectiveness. An important step then in improving team communications is the identification and measurement of critical communications variables. This paper documents the investigative efforts of the Construction Industry Institute (CII) Project Team Communications research team in achieving this consequential first step.

BACKGROUND

Numerous studies have highlighted the importance of effective communications for project success. Thamhain and Wilemon (1986), in a study of engineering organizations, listed "communicating effectively among task groups" the third most significant factor contributing to project success. Through further analysis Thamhain concluded that the top 30 potential problems contributing to poor project performance could be classified using the following five categories (Thamhain 1992):

1. Problems with organizing the project team
2. Weak project leadership
3. Communication problems
4. Conflict and confusion
5. Insufficient upper-management involvement

Although communication problems are listed as the third category, all five categories involve communications to some extent. For example, organizing a project team clearly requires effective communication, and conflict and confusion are results of poor or ineffective communication. The importance of effective communications to project success is documented routinely in CII literature. A cursory electronic search of its publications reveals that 129 of 173 documents address communications in some manner (CII 1995). Stark statements concerning the importance of effective communications, statistically backed by comprehensive research efforts, appear in several CII publications. In *Guidelines for Implementing A Constructability Program*, the authors note that "... team and communication skills are equally as important as their technical specialty skill" (CII 1987). Publication 14-2, *An Assessment of Education and Training Needs Among Construction Personnel*, concludes "communication skills are important at all levels of performance and should be included in most continuing education programs" and "communication is the most important skill/trait needed to achieve high positions in construction organizations" (CII 1992). This research confirms the beliefs of many project managers that "the single most important factor that contributes to successful project management is communications" (CII 1986).

Although most managers agree that effective communications are critical to project success, little progress has been achieved toward improving communication effectiveness. Consistent with the supposition, "what gets measured, gets done," a necessary step in bettering project communications is the identification and measurement of critical communications variables.

Research Team

The CII commissioned the Project Team Communications research team to investigate the potential for enhanced project success through improvements in project team communications. This team consisted of 14 individuals from academia and member companies. The primary objective of the research was the development of a diagnostic tool for improving project team communications. In pursuit of this objective, the research team identified critical communications and success variables and established the relationship between communications effectiveness and project success.

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Project Team

Project teams are "... organizational entities devoted to the integration of specialized knowledge for a common purpose" (Cleland 1995). Team members include representatives from "owner, designer, contractor, and other stakeholder organizations" (CII 1993). Considering the number and varied responsibilities of project team members, the research team decided to focus its research on first-line supervisors during the design and construction phases of the project. Critical communication interfaces are present at this level that influence the bulk of work hours expended on the project. Communication problems, if they exist on the project, should be apparent and will be exacerbated at the first-supervisor level if information is incorrect or does not flow smoothly. For purposes of this research, first-line supervisors were defined as the following:

- Lead design engineers
- Lead estimating, cost, and schedule engineers
- Lead procurement and material control staff
- Lead safety and quality assurance/quality control (QA/QC) personnel
- Lead accounting representatives
- Lead construction supervisors including foremen

Communications Theory

Communication is "the process of effecting an interchange of understanding between two or more people" (Flippo and Munsinger 1975). In its simplest conception, it is the sending and receiving of information between team members. However, in reality, it is a "complex process" assuming various representations from respective authors (Sigband and Bell 1989). An analysis of these representations reveals a common set of elements essential to an understanding of communications theory. These elements, depicted in Fig. 1, reflect an adaptation of the "interpersonal communication model" (Schermerhorn et al. 1994) and the "communication process" described by various authors (Sigband and Bell 1989; Gibson and Hodgetts 1990; Loo 1995). A discussion of the elements is provided in the following sections.

The Sender

As the originator of the communication, the sender knows best the intended idea and must encode the idea into the message to be sent.

The Receiver

Comprehension of the message by the receiver depends on a number of factors including how much the individual knows about the topic, "receptivity to the message," the relationship and trust that exist between sender and receiver, and "the receiver's understanding and perception of the information being conveyed" (Gibson and Hodgetts 1990).

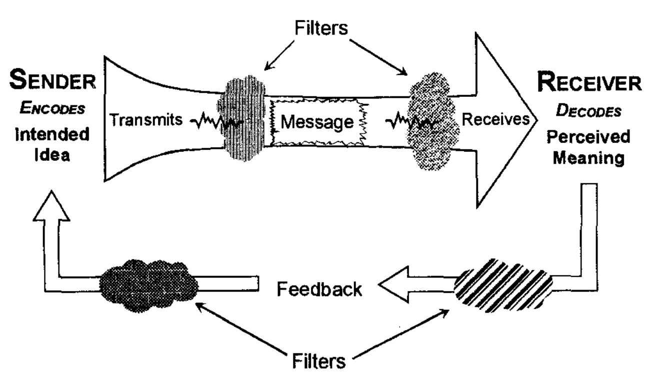

FIG. 1. Communications Process

The Message

The message is the encoded idea being transmitted and can be verbal or nonverbal.

Channels

Conduits through which messages flow can be formal, following organizational lines, or informal with virtually any structure. Formal channels usually flow downward and often tend to be directive (Sigband and Bell 1989). They transmit schedules, memos, change orders, policies, etc. These channels also can be useful in keeping employees informed by transmitting newsletters and performance data. Formal, vertical channels also are used to keep senior management informed; project progress and cost data are passed upward through these channels on a routine basis. However, the upward flow of other information may be less effective because these channels are often regulated for specific purposes.

If adequate communication does not take place in formal channels, "... it will surely take place by means of informal ones" (Sigband and Bell 1989). These informal channels, often called the "grapevine," are used when formal channels fail to satisfy an individual's information requirements (Sigband and Bell 1989). Informal, lateral or diagonal, channels of communications are often the least efficient "... because there is rarely pressure to communicate in that direction" even though these channels carry many messages vital to project success (Wofford et al. 1977; Sigband and Bell 1989). Informal channels normally evolve on projects and may prove to be of equal or greater value than formal channels. While surveying companies for their national bestseller, *In Search of Excellence*, Thomas Peters and Robert Waterman Jr. (Peters and Waterman 1982) noted informal communications to be a "unanimous characteristic" of America's best run corporations. Although it may be premature to conclude a causative relationship between informal communication and the success of an organization, the findings of Peters and Waterman suggest the possibility and, therefore, the research team gave particular attention to informal channels of communication throughout its research.

Media

The media for communications, often categorized as hard or soft, is dictated by the channel. Examples of hard media include contracts, procedures, plans, reports, policies, and regulations. Communications using hard media generally have structure, formal control, are system generated, and utilize formal channels. Representative project activities using hard media include design-construction progress review meetings, the submission, review and approval of vendor-subcontractor drawings, and the processing and review of accident reports. Communications using soft media, as expected, usually are less structured, frequently verbal, less formal, and maybe even ad hoc. Examples of such communications include team building sessions, "brown bag" meetings/discussions, disputes, and person-to-person exchanges. These activities usually take place in informal communication channels, although they can often spill over into formal channels.

Communication Barriers and Filters

Barriers and filters are aspects of communication systems that limit information flow or "color" information as it is transmitted (Flippo and Munsinger 1975). They can be related to interpersonal issues such as bias and prejudice, or they can

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TABLE 1. Impact of Organizational Layers

Level (1)	Percent of information received (2)
Board	NA
Vice president	63
General supervisor	56
Plant manager	40
General foremen	30
Workers	20

NA, not applicable.

stem from poor education and lack of training. Communication skills beyond basic reading and writing are seldom taught in undergraduate or secondary schools and for most project participants are learned through experience. Language is often "the most common barrier to effective communication" as noted by Sigband and Bell (Sigband and Bell 1989) in quoting Mark Twain, "There is as much difference between the right word and the almost-right word as between lightning and lightning bug." Semantics play a significant role in accurate communications and "semantic distortion occurs in the communications process because our code fails us" (Wofford et al. 1977). Considering the various backgrounds, education levels, language, and cultural differences of project participants, the existence of communications problems should be no surprise.

Project characteristics such as organizational structure, size, and location also influence the effectiveness of communications. Poor organizational structure results in inadequate representation of project stakeholders contributing to a lack of essential information. Too many layers of organization can be equally bad ". . . as the number of organizational filters increases with the levels of organization" (Flippo and Munsinger 1975). The results of one study provided in Table 1, clearly show this impact (Gibson and Hodgetts 1990). Workers at the lowest levels of the organization were shown to receive as little as 20% of the information disseminated. Even at the upper levels, vice presidents, second in the chain, received only 63%. Channels can overload from too many organizational levels and, without adequate controls, contribute to technical system failures. Excessively long channels, sometimes caused by remote project locations, further inhibit communications flow. Barriers and filters impeding or altering the flow of communications exist to some degree in all communications systems. Aware of the importance of barriers, the research team sought to identify them, their locations, and their impact on the project's communications effectiveness.

Feedback

The receiver's response to a message provides feedback to the sender. It can be verbal or nonverbal but is essential for the accurate completion of the communications process. Without feedback, the sender does not know if the message was received and understood.

Communication, as depicted, is a process. The number of senders, receivers, channels, filters, and media is dynamic. Throughout the project's life cycle as members join and leave the team, new channels are created and deleted. As participants are trained or gain experience, barriers are eliminated and filters are improved. Communication effectiveness depends not only on the interchange between participants, but more importantly, the understanding between them.

This brief review of the project team and communication theory provided the foundation for the effective analysis of team communications. The complex nature of the project team, various organizations represented by the team, and at times, competing interests of team members all serve to complicate team communications. The research team met approximately every other month for a year brainstorming the interaction of these elements and used an expert moderator to guide work sessions as it strengthened its foundation in communications theory in pursuit of its objectives.

Project Success

The research team posited a direct relationship between communications effectiveness and project success. Establishment of this relationship required the identification and measurement of both communications and success variables.

Many studies have focused on characteristics of successful projects. Some, particularly in the 1980s and 1990s, identified critical factors contributing to project success (Sanvido et al. 1992). In the CII research report "Perceptions of Project Representatives Concerning Project Success and Pre-Project Planning Effort," (Gibson et al. 1994) team factors affecting project success are documented. Most of these factors include subjective elements rendering them difficult to quantify. Attempts to find objective measures of project success revealed a study by Ashley et al. (1987) in which success was measured by "cost, schedule, quality, safety, and participant satisfaction." Although somewhat easier to quantify, some of these measures, and in particular participant satisfaction and quality, remain quite subjective. In a later study by Thamhain (1992) over 60% of engineering managers surveyed agreed that the top three characteristics of a successful project include the following:

1. Technical project success, measured according to agreed-upon objectives
2. On-time performance
3. On-budget performance

These results are consistent with research by the CII into the relationship between preproject planning and project success. The CII research identified four significant variables for measuring project success: "budget achievement, schedule achievement, design capacity, and plant utilization" (Gibson and Hamilton 1994). Design capacity is the nominal output rate of a facility such as barrels per day, kilowatts, etc. Plant utilization is the percentage of days in a year that the plant actually produces. Both design and plant utilization are measures of success according to agreed-upon objectives similar to Thamhain's first characteristic mentioned earlier.

Findings of these studies assisted the research team in identifying variables measuring project success. Specific questions were formulated addressing safety, schedule, budget, and rework. It is important to note that the research team decided to investigate perceptions of project success rather than specific measures of project success. The objective of the team was to develop a tool for measuring communications effectiveness. Questions assessing communications effectiveness are based on perceptions; therefore survey respondents' perceptions of project success are appropriate for the analysis and specific measures of project success are not necessary.

RESEARCH METHODOLOGY

The specific methodology used to identify critical communications variables is shown in Fig. 2. Two phases, questionnaire development and data collection and analysis, are described in the following paragraphs and specific findings of the data analysis are provided in a subsequent section.

Although several data collection alternatives were available to the research team, the survey questionnaire was deemed most efficient. Thus, the research process commenced with the questionnaire development activities of literature review, issue

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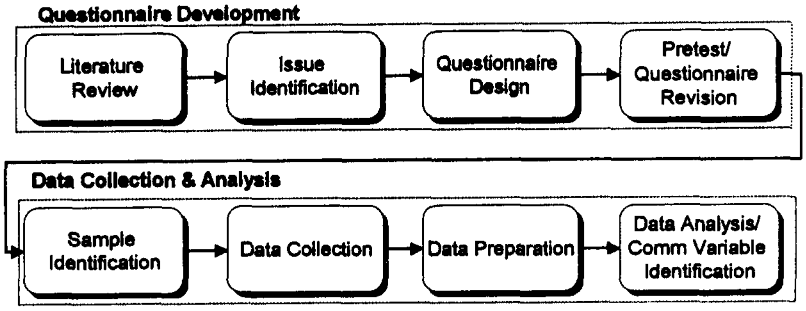

FIG. 2. Research Methodology

identification, questionnaire design, and pretest-questionnaire revision. The literature review provided a foundation for the identification of general communication and success issues. These issues were identified through the research team brainstorming the dimensions of communications and project success. For communications these dimensions include the elements of the communications process provided in Fig. 1. For project success, schedule and budget performance as well as quality and safety issues dominated the discussions. These quantifiable issues were balanced with the issues of satisfaction and overall perception of project success.

Many communication problems were assumed to be specific to particular groups, phases of a project, and work performed. For instance, delays caused by communication problems with suppliers, department reviews, or client approval may be specific to the design group, whereas communication problems relating to material delays or equipment availability may be unique to the construction group. For this reason, the research team decided to develop three separate questionnaires. The project management (PM) questionnaire captured overall project issues, the engineering (ENG) questionnaire captured design issues, and the construction (CON) questionnaire targeted construction issues. All questionnaires were designed for first-line supervisors.

Questionnaire pretesting was conducted using research team member projects. More than 100 completed questionnaires were collected from approximately 30 projects providing valuable comments for questionnaire improvement. Following the pretests, the research team revised the questionnaires and proceeded with data collection and analysis.

Thirty-eight CII member organizations supported the next phase of the research, data collection and analysis. The organizations volunteering projects included 35 owner and contractor firms and three government agencies. A variety of project types, widely disbursed geographically, were nominated. To ensure that projects sampled were capable of providing data representative of the three survey groups, the research team sought to qualify these projects. This qualification had to be done with due concern for the randomness of the sample for the statistical results to be used in making inferences about the population. Research team members personally called project contacts, explaining the nature of the research and characteristics of projects desired. The team sought to qualify projects to be accepted with the following criteria. Projects should be in progress, or if complete, recently completed ensuring access to project team members. Projects should have a total installed cost of at least $5,000,000. The engineering, procurement, and construction (EPC) projects were deemed ideal, providing the greatest range of data from all three survey groups. Most projects surveyed met these criteria; however, numerous exceptions were included. Of the 740 questionnaires distributed, 608 completed questionnaires were returned, representing a return rate of 82%, thus reflecting significant interest in the subject. After screening for discrepancies, a total of 582 returned questionnaires representing 72 projects were determined adequate for analysis.

Proper data analysis requires effective data preparation and management. The length of the questionnaire, the number of completed surveys anticipated, and the data analysis software to be used all had to be considered in selecting a database-management system. The relational database-management program, Microsoft Access version 2.0, was chosen for this purpose. Survey responses were coded and recorded in the database. Both quantitative and nonquantitative, open-ended responses, were recorded. Open-ended, verbatim responses were recorded for possible future analysis and frequently served to clarify quantitative responses and missing data.

Two common methods exist for analyzing cases with missing data. Cases can be excluded "listwise," whereby all variables are retained, but cases with missing data are eliminated (Norusis 1993). This approach is reasonable if sufficient responses are received so that statistically significant results can be obtained after removal of cases with missing data. The alternative is "pairwise" exclusion where the analysis of variables is based on all cases with complete data, regardless if there are missing data for other variables (Norusis 1993). Because analysis is based on all cases that have valid coded responses for a particular pair of variables, "pairwise" exclusion maximizes information available in every calculation (Norusis 1993). Pairwise exclusion was used for this analysis.

Analysis of the data commenced with an investigation of the descriptive characteristics of the sample using Microsoft Excel and proceeded to statistical analyses of the relationship between communications effectiveness and project success. Establishment of this relationship would indicate the questionnaire's ability to measure communications effectiveness. The Statistical Package for Social Scientists (SPSS) version 6.1 was used for the statistical analyses.

A bivariate correlation analysis was performed for each survey group permitting the identification of significant success and communication variables. These variables were collapsed into success and communications indexes, tested for reliability, and then used in regression analyses to establish the relationship between perceptions of communications effectiveness and project success. Scatter plots were first generated for each survey group and then for an aggregate of the groups graphing communications effectiveness as the independent variable and project success as the dependent variable. These plots graphically demonstrated the strength of relationship for the indexes. A regression line was fit to the data and the coefficient of determination R^2 calculated as a "measure of the goodness of fit" to the regression line (Norusis 1993). Results of these analyses are provided in the Data Analysis section.

The next step was to identify categories consolidating the significant communications effectiveness variables. After some debate the research team concluded that these variables fit well into six categories capturing the essential elements of effective communications. These categories can be used to quantify a

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project's communications effectiveness and ultimately support a program for improving project communications. Weights also were developed for each category reflecting its relative importance for effective communications. Categories and weights are presented in the next section.

DATA ANALYSIS

Data were collected from 38 CII organizations for 72 projects geographically dispersed in eight separate countries. A proper analysis requires investigation of the descriptive characteristics of these projects as well as statistical analyses of the communications and success variables. These analyses are presented in the following sections.

Descriptive Analysis

Tables 2–4 summarize descriptive data for the projects surveyed and Fig. 3 expands upon these data. CII research report 105-11 provides a detailed presentation of these data (Tucker et al. 1996).

The 582 questionnaires analyzed consist of 173 PM, 167 ENG, and 242 CON. The most common type of facility in the sample is the process plant followed by civil-commercial and power projects. Most projects are new construction and about 28% revamp. Projects surveyed vary in size from $4,000,000 total installed cost to $1.3 billion. The $1.3 billion project and two $1.0 billion projects are outliers that tend to distort the mean of cost data as is evident upon examination of the median. The total installed cost for the entire sample is $9.3 billion. Contract types are split almost evenly between lump sum and a form of reimbursable contract. Combinations of contract arrangements are common. Most contracts provide for EPC services; the large number of projects in the "other" category indicates many respondents provided two or more services such as engineering and procurement or engineering and construction. The percent complete at the time of survey varies significantly; the median of 75 results from a number of completed projects.

TABLE 2. Project and Respondent Characteristics

Project/respondent characteristic (1)	Responses (2)	Number (3)	No response (4)
Response provided by owner or contractor representative?	Owner	30	
	Contractor	39	3
Type of facility	Civil-commercial	14	
	Process	32	
	Power	13	1
	Environmental	7	
	Other	5	
Type of project	Revamp	20	
	Greenfield	43	
	Expansion	2	0
	Remedial	6	
	Other	1	
Public or private	Public	18	0
	Private	54	
Joint venture	Yes	15	0
	No	57	
Total installed cost ($M)	Minimum	4	0
	Maximum	1,333	
	Mean	129.54	0
	Median	67.45	
	Standard deviation	230.45	
Type of contract	Lump sum	35	
	Cost reimbursable	20	
	Cost plus percentage	4	0
	Guaranteed maximum price	3	
	Combination	10	
Services provided	EPC	36	
	Engineering	2	
	Construction	6	3
	Construction management	6	
	Other combination	19	
Schedule duration (months)	Minimum	3	
	Maximum	120	
	Mean	29.2	0
	Median	24	
	Standard deviation	18.65	
Percent complete at survey time	Minimum	1	
	Maximum	100	
	Mean	66.7	1
	Median	75.0	
	Standard deviation	33.8	
Project location	Domestic	65	0
	International	7	

TABLE 3. Project Management Approach

Management approach (1)	Response (2)	Number (3)	No response (4)
Partnering/alliances used	Yes	41	4
	No	27	
Formal team building used	Yes	44	4
	No	24	
Organizational structure	Task force	52	
	Matrix	11	6
	Both	3	
Labor arrangement	Union	31	3
	Merit	38	
Constructability program used	Yes	44	7
	No	21	
Project execution plan used	Yes	59	0
	No	13	

TABLE 4. Project Performance Data

Performance data (1)	Response (2)	Number (3)	No response (4)
Schedule performance	Ahead	15	
	On	41	1
	Behind	15	
Budget performance	Within budget	59	1
	Exceeding budget	12	
Amount of rework	Below average	27	
	Average	38	0
	Excessive	7	

The map provided in Fig. 3 reflects the dispersion of the sample studied. Although most projects were domestic, international projects were included where adequate data could be collected.

Strictly speaking, random sampling techniques were not employed. CII member firms nominated projects for the study from their portfolio of projects and the research team qualified these projects to ensure that they appeared representative of the CII at large. Examination of the descriptive data reveals the sample is typical of CII projects; therefore the statistical analysis of data from this research probably can be applied to the broader CII population.

Statistical Analysis

The survey questionnaires for each group, PM, ENG, and CON, contained approximately 54 communications effectiveness and six project success questions. A sample of communications questions is provided in Appendix I. Question format varied including multiple choice, rank on scale, and open-ended. In addition, the PM questionnaire included 25 profile questions to collect descriptive data. The questions are similar for each group except a series of delay questions specific for engineering and construction. Complete copies of each questionnaire are included in CII research report 105-11 (Tucker et al. 1996).

The initial statistical analysis determined the correlation between communications effectiveness variables and a global communications effectiveness question for each survey group. Similarly, correlations were then determined for success variables and a global success question for each group. This was accomplished by performing six bivariate correlation analyses producing six correlation matrices: PM communications, PM

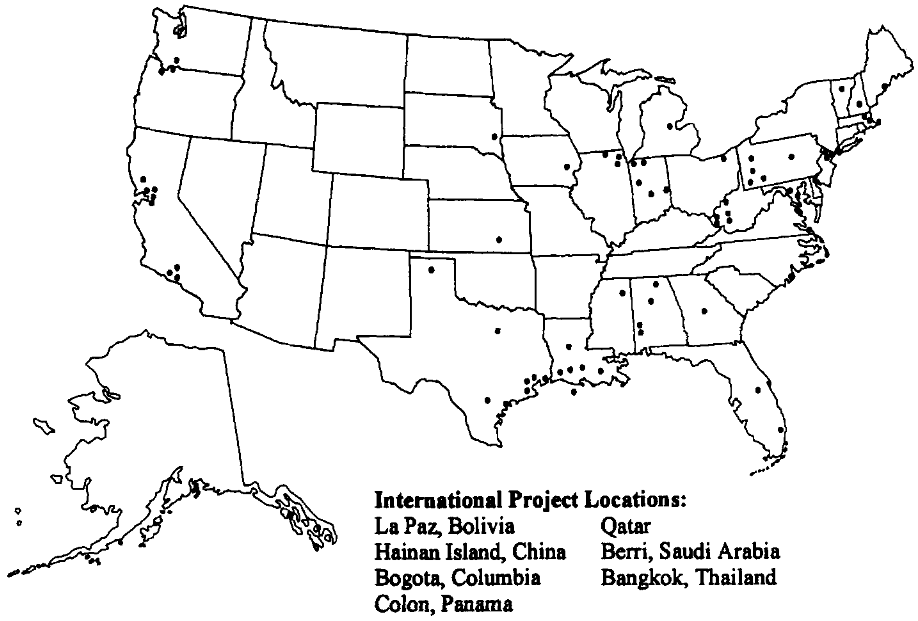

FIG. 3. Project Locations

TABLE 5. Well-Correlated and Significant Variables

Question number (1)	Question description (2)	PM (3)	ENG (4)	CON (5)
	(*a*) Communications effectiveness questions			
4s	Do you understand what your supervisor expects from you?		•	
4o	Do you understand what other groups expect from you?		•	
9a	Frequency of conflicting instructions		•	
10	Frequency of poor communications/lack of coordination	•	•	•
17b	How effective are these procedures?	•		•
18	Project execution plan used on a regular basis	•		
19a	Kept current with design changes		•	
19b	Kept current with schedule changes		•	
20	Adequate access to people with necessary information	•		•
22	Frequency of not enough information			•
24	Perception of communications effectiveness	•	•	•
	(*b*) Project success questions			
15	Project within budget?			•
16	Amount of rework		•	
26	Perception of project success	•	•	•

Note: Variables indicated were correlated at 0.4 or above with a significance of 0.1 (correlation coefficients were rounded to tenths during selection).

TABLE 6. Index Construction

Index (1)	Variables (2)
PM success index	PM26
PM communications index	PM10 + PM17b + PM18 + PM20 + PM 24
ENG success index	ENG16 + ENG26
ENG communications index	ENG4a + ENG4s + ENG9a + ENG10 + ENG19a + ENG19b + ENG24
CON success index	CON15 + CON26
CON communications index	CON10 + CON17b + CON20 + CON22 + CON24

TABLE 7. Reliability Test Results

Index (1)	α (2)	Variables (3)
PM success	NA	PM26
PM communication	0.6698	PM10, PM17b, PM18, PM20, PM24
ENG success	0.5740	ENG16, ENG26
ENG communication	0.8157	ENG40, ENG45, ENG9a, ENG10, ENG19a, ENG19b, ENG24
CON success	0.3748	CON15, CON26
CON communication	0.7156	CON10, CON17b, CON20, CON22, CON24

NA, Not applicable.

success, ENG communications, ENG success, CON communications, and CON success. Statistical criteria were then developed to evaluate correlations; variables correlated at the 0.4 level or above with a significance of 0.1 or less were determined important enough for further analysis. Table 5 summarizes the variables (questions) that met these criteria. Specific wording of the questions is provided in CII research report 105-11 (Tucker et al. 1996).

Statistical indexes were constructed from these variables to reduce the number of variables, thus simplifying the analysis. Variable responses were added as shown in Table 6 to construct the indexes.

Prior to using these indexes further in the statistical analysis, a reliability assessment was performed for each index to ensure "internal consistency" of the component variables (Knoke and Bohrnstedt 1994). This assessment was performed using SPSS and Cronbach's Alpha. Calculation of this parameter for each combination of variables in the index reveals variables detracting from the strength of the index, indicating that they should be omitted. The parameter results, which "can range from zero for no internal consistency" to "one for perfect internal consistency," are summarized in Table 7 (Knoke and Bohrnstedt 1994). A complete listing of index calculations and reliability test results is available in CII research report 105-11 (Tucker et al. 1996). No variables were dropped from any of the indexes as a result of reliability testing. Although alphas (α) of 0.7 or higher are desirable, lower values are acceptable and are to be expected with few index variables

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(Knoke and Bohrnstedt 1994). Lower test results for ENG success and CON success reflect the relatively low number of variables comprising the indexes. Reliability testing was not performed for the PM success index, because it contains only one variable.

The relationship between project success and communications effectiveness was determined for each survey group by performing regression analyses using success and communications indexes. Because the number of questionnaires varies considerably among projects, a single project potentially could have a disproportionate influence on the results. To address this concern, responses for each project were averaged prior to the regression analysis. Scatter plots were then created plotting communications effectiveness as the independent variable and project success as the dependent variable. A regression line was fit to this data and the coefficients of correlation and determination were calculated. Table 8 summarizes these findings. The correlation coefficient, which can vary from 0 to 1, reveals the "direction and strength" of the association (Lewis-Beck 1980). The coefficient of determination R^2 records the proportion of variation in the dependent variable (project success) explained or accounted for by variation in the independent variable (communications effectiveness) (Lewis-Beck 1980). Although both statistics are important to the analysis, "R^2 is the preferred measure" (Lewis-Beck 1980). Relying on r rather than R^2 can make the impact of the independent variable on the dependent variable appear much greater than it is, particularly at the extremes of r (Lewis-Beck 1980).

Although the statistics are noticeably higher for the PM and ENG groups, all three groups are within an acceptable range. The PM and ENG data reveal strong correlation between communications effectiveness and project success. However, it is important to remember that many factors other than communications effectiveness contribute to project success. The lower correlation for the CON group may simply reflect this reality. The PM and ENG coefficients of determination indicate that nearly one-half of the variation in the perception of project success can be attributed to variation in the perception of communications effectiveness. The lower statistics for construction may indicate that their criteria are based on a different set of issues. Because the construction group typically enters the project at a later date, different factors are present affecting project success, thus changing the proportion attributed to communications. Both PM and ENG influence a project earlier in its life cycle and may have a greater impact on overall project success. However, the lower CON results have no bearing on the validity of the diagnostic tool.

TABLE 8. Regression Summary

Survey group (1)	Correlation coefficient (r) (2)	Coefficient of determination (R^2) (3)
PM	0.72	0.52
ENG	0.71	0.49
CON	0.45	0.20

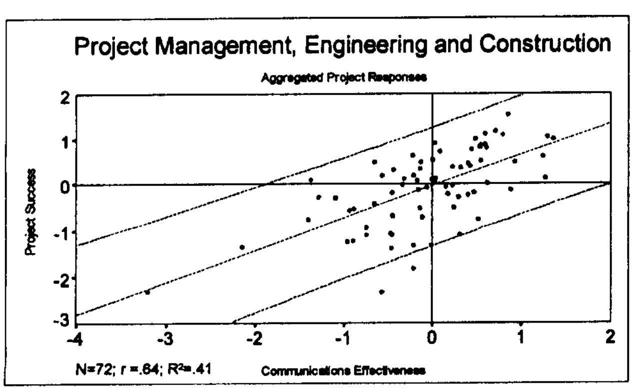

FIG. 4. Aggregated Group Regression Summary

The analysis presented thus far establishes the relationship between project success and communications effectiveness for each survey group. An analysis of this relationship at the project level requires aggregation of group data. Because the PM, ENG, and CON indexes contain variables of different scales, the indexes had to be normalized before aggregation. This was accomplished by subtracting the mean of all group responses and dividing by their standard deviation. The normalized (Z score) index values of each survey group were then averaged accounting for the different number of variables in each index in forming the aggregated indexes for communications effectiveness and project success. A scatter plot of the aggregated indexes was generated, the data fit with a regression line, and the correlation coefficient and coefficient of determination calculated as before. Fig. 4 shows these data with a 95% confidence band.

With a correlation of 0.64, this plot clearly depicts the positive relationship between communications effectiveness and project success. The R^2 of 0.41 suggests that variation in the perception of communications effectiveness accounts for 41% of the variation in the perception of project success.

CRITICAL CATEGORIES OF COMMUNICATIONS

Having identified critical communications effectiveness variables and having determined the relationship between these variables and project success, the final step in this analysis was to consolidate these variables and quantify their relative importance for future use. After some debate, the research team concluded that these variables fit well into six categories. These categories and their component variables are presented in Table 9. Weights were developed for each category reflecting the category's relative importance for effective communications. The weights were obtained by summing correlation coefficients for component variables by category and normalizing these sums to a 0–10 scale. Specific details of weight calculations are included in CII research report 105-11 (Tucker et al. 1996).

The accuracy of information can be measured by the frequency of conflicting information, lack of coordination, or other indicators of poor communications. A project execution plan or similar document may be used to define formal project procedures, methods, and the scope of work. Barriers and filters restricting communications flow may be the most difficult

TABLE 9. Critical Categories of Communications

Category (1)	Description (2)	Question(s) (3)	Weight (4)
Accuracy	The accuracy of information received as indicated by the frequency of conflicting instructions, poor communications, and lack of coordination.	11, 12	2.1
Procedures	The existence, use, and effectiveness of formally defined procedures outlining scope, methods, etc.	19, 20	1.9
Barriers	The presence of barriers (interpersonal, accessibility, logistic, or other) interfering with communications between supervisors or other groups.	23	1.8
Understanding	An understanding of information expectations with supervisors and other groups	4s, 4o	1.6
Timeliness	The timeliness of information received including design and schedule changes.	22a, 22b	1.4
Completeness	The amount of relevant information received.	24	1.2

category to improve. They may be the result of interpersonal problems beyond the ability of the project manager to solve. Others barriers can be reduced through training. An understanding of information requirements and expectations is likewise difficult to diagnose and remedy. The lack of understanding may be present long before the symptoms are apparent. The fifth category, a lack of timely information is a common problem for engineering and construction projects; fortunately, most project managers would be comfortable in developing procedures to address the problem. The final category, completeness of information can result from the existence of problems within the other categories.

The significance of these findings should not be overlooked. For the first time, critical variables of communications have been identified through the collection and analysis of data from a large sample of engineering and construction projects. These data have been reduced to a manageable number of quantifiable categories that can be used to formulate a communications improvement strategy. The project manager can now better focus efforts for improving communications.

CONCLUSIONS

The lack of effective communications continues to be a major obstacle to project success. Reputable studies document this conclusion; however, little progress has been achieved toward a solution. The five categories of problems contributing to poor project performance identified by Thamhain (1992) have one thing in common; they all stem from humanistic issues. Organization problems, poor leadership, ineffective communications, conflicts/confusion, and insufficient upper-management involvement are all management issues, difficult to quantify, which without doubt contribute to poor project performance. Other measures of project success: achievement of technical goals, schedule, budget, and quality performance are more readily quantified and directly benefit from advances in technology. The humanistic issues can be and are being addressed through training and higher education. However, these efforts can be enhanced through a systematic approach to identifying and measuring critical performance variables. This study achieved a milestone for engineering and construction projects by identifying such variables for team communications. Survey questionnaires were developed for use on a large sample of CII projects providing essential data from which the research team identified the variables contributing to effective communications. These variables were categorized as accuracy, procedures, barriers, understanding, timeliness, and completeness. The relative importance of these variables was established by a system of weights based on the strength of statistical correlations determined in the analysis. These variables can now be used to measure the effectiveness of communications on other projects and provide a basis for improving team communications. Project managers in engineering and construction can use questionnaires similar to those developed by the research team to assess the effectiveness of communications on their projects. The results obtained can be used to develop strategies to remedy communications problems.

This study has established a positive and quantifiable link between communications effectiveness and project success. The statistical analysis reveals that 41% of the variation in perceptions of project success can be attributable to variation in communications effectiveness. This direct relationship strongly suggests that improving project communications can enhance project performance and the variables identified through this study provide the means to do so.

RECOMMENDATIONS

The writers recommend that engineering and construction organizations pursue a program to improve communications effectiveness. The first step in this process should be the development of a means to assess the current status of project communications. This can be accomplished by conducting a study similar to that commissioned by the CII. Considering the large sample of CII projects surveyed for this study, the results are likely to be representative for similar projects. Other firms may therefore benefit by using the results of this study directly for their projects. However, identification of communications problems is only the first step in the process. A program of periodic reassessment and procedures to improve communications using the finding of this study also must be developed.

APPENDIX I. SAMPLE COMMUNICATIONS QUESTIONS

How well do you understand what information your supervisor and other groups on this project expect from you?

Supervisor

- □ Very well
- □ Somewhat well
- □ Not too well
- □ Not at all well

Other Groups

- □ Very well
- □ Somewhat well
- □ Not too well
- □ Not at all well

How well do you understand your roles and responsibilities on this project?

- □ Very well
- □ Reasonably well
- □ Not too well
- □ Not at all well

Are there any factors that interfere with you communicating with your boss(es)?

- □ Yes (please go to 7)
- □ No (please go to 8)
- □ Don't know (please go to 8)

Are these factors _______ ? (Please check all that apply.)

- □ Interpersonal issues
- □ Accessibility issues
- □ Logistic/scheduling issues
- □ Other (please specify ______________________)

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