Critical Success Factors for Construction Projects

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Abstract: A building project is completed as a result of a combination of many events and interactions, planned or unplanned, over the life of a facility, with changing participants and processes in a constantly changing environment. This paper defines a set of conditions or factors that, when thoroughly and completely satisfied on a project, ensures the successful completion of the facility. Success on a project means that certain expectations for a given participant were met, whether owner, planner, engineer, contractor, or operator. These expectations may be different for each participant. The factors that predicate success were initially derived from the Integrated Building Process Model developed at Penn State by Sanvido in 1990. These factors were then tested on sixteen projects and the results showed excellent correlation between project success and achievement of the factors. Finally, the four factors most critical to success are presented.

Introduction

A building project is completed as a result of a combination of many events and interactions, planned or unplanned, over the life of a facility, with changing participants and processes in a constantly changing environment. Certain factors are more critical to project success than others. These factors are called critical project success factors (CPSFs).

The term "critical success factors," in the context of projects and the management of projects, was first used by Rockart (1982). The topic has since become a prolific research area. Furthermore, because the pursuit of excellence in project delivery systems is not new, this new research direction could thrive upon a rich legacy of many previous investigators.

Unfortunately the promises of critical success factor research have not been fully realized. Despite nearly a decade's subsequent work, the construction industry is substantially unchanged, and we have only a marginally better understanding of the factors that make projects successful.

Objective and Significance

The objective of this research is to define the critical factors that lead to project success and provide a forecasting tool to enable parties to rapidly assess the possibility of a successful project from their viewpoint.

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If project participants can predict probability of success better, they can take steps to: (1) Avoid unsuccessful projects; (2) identify good projects worth pursuing; and (3) identify problems on current projects and take corrective action.

The general objectives were met through accomplishment of several specific tasks.

Research Tasks

The following research tasks were completed.

- Define the project success criteria
- Define the ideal facility life-cycle functions
- Develop structured questionnaire
- Select projects
- Collect data from sites
- Analyze data
- Develop guidelines for CPSFs

DEFINITION OF SUCCESS

The literature on critical success factors reveals several somewhat conflicting definitions of "project success." The following is a sampling of the various proposals, discussions, and definitions.

> results much better than expected or normally observed in terms of cost, schedule, quality, safety, and participant satisfaction [Ashley (1987)].

> having everything turn out as hoped . . . anticipating all project requirements and have sufficient resources to meet needs in a timely manner [Tuman (1986)].

> quality is defined as the totality of features, attributes, and characteristics of a facility, product, process, component, service, or workmanship that bear on its ability to satisfy a given need: fitness for purpose. It is usually referenced to and measured by the degree of conformance to a predetermined standard of performance [ASCE: *Quality* (1988)].

> The project is considered an overall success if the project meets the technical performance specifications and/or mission to be performed, and if there is a high level of satisfaction concerning the project outcome among: key people in the parent organization, key people in the project team, and key users or clientele of the project effort [de Wit (1986)].

Ashley (1987) refers to project success as having results "much better than expected;" other authors seem to restrict their expectations to a mere meeting of the technical specifications and mission. It is not clear at this point which of these viewpoints represent the expectations of the majority of project participants.

As Morris (1983) aptly stated [and de Wit (1986) alluded]: "any study of

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success and failure in projects must before long decide what is meant by success: for whom? using what criteria? and over what time period?" It is in this area that most previous studies presented a limited view of project success. If success was defined, it was often unclear from whose perspective, or at what point in the project life cycle it was measured.

The literature has given several definitions of success, each of which is specific to a particular project. We believe that each project participant will have their own viewpoint of success. Success for a given project participant is defined here as the degree to which project goals and expectations are met. These goals and expectations may include technical, financial, educational, social, and professional aspects. These expectations may be different for many project participants, and are discussed below.

Success Criteria

Success criteria or a person's definition of success as it relates to a building often changes from project to project depending on participants, scope of services, project size, sophistication of the owner related to the design of facilities, technological implications, and a variety of other factors. On the other hand, common threads relating to success criteria often develop not only with an individual project but across the industry as we relate success to the perceptions and expectations of the owner, designer, or contractor. Differences in a person's definition of success are often very evident.

To orient the researchers, lists of typical success criteria for the owner, designer, and contractor were developed. Each list was developed by the writers' reviewing the literature and then brainstorming and discussing success criteria for the owners, designers, and contractors represented on the project team. An unprioritized summary of these success criteria follows.

Owner's criteria for measuring success: on schedule; on budget; function for intended use (satisfy users and customers); end result as envisioned; quality (workmanship, products); aesthetically pleasing; return on investment (responsiveness to audiences); building must be marketable (image and financial); and minimize aggravation in producing a building.

Designer's criteria for measuring success: satisfied client (obtain or develop the potential to obtain repeat work); quality architectural product; met design fee and profit goal; professional staff fulfillment (gain experience, learn new skills); met project budget and schedule; marketable product/process (selling tool, reputation with peers and clients); minimal construction problems (easy to operate, constructible design); no "ghosts," liability, claims (building functions as intended); socially accepted (community response); client pays (reliability); and well defined scope of work (contract and scope and compensation match).

Contractor's criteria for measuring success: meet schedule (preconstruction, construction, design); profit; under budget (savings obtained for owner and/or contractor); quality specification met or exceeded; no claims (owners, subcontractors); safety; client satisfaction (personal relationships); good subcontractor buy out; good direct communication (expectations of all parties clearly defined); and minimal or no surprises during the project.

Common Criteria

While many criteria items or viewpoints are similar, there are several distinctions that relate directly to the parties involved and the type of business services they provide. For example, a priority item and one that appears in all three lists (designer, owner, and contractor) in some form is the financial reality of doing business. The owner wants the project completed on time and on budget, and the designer and contractor both expect to meet certain profit or fee goals. All three viewpoints also recognize the absence of any legal claims or proceedings on a project as a desirable outcome. In other words, this is a major criteria for measuring success. Another common thread among the three groups involves meeting an appropriate schedule as a way of measuring or determining if a project was successful.

Unique Criteria

It is also evident that there are some unique factors associated with each of the three groups. The designer for instance is looking for a project that will increase the level of professional development and professional satisfaction among his employees. Safety is a high-priority issue for the contractor that would not normally be an issue with the other two groups, because their employees are at much less risk during the design or operation of a building than the contractor's workers are during the construction of a building. An owner is extremely interested in knowing that the building project functions properly for the intended use and is free from long-term defects or lingering maintenance problems.

As one would suspect, there is some variability even within the same firm on the same project. The factors of importance range from meeting internal budgets to professional satisfaction and on to producing a job that will help the firm obtain repeat business or serve as a marketing tool for similar projects with different clients. For example, two designers working on the same project may view success differently. An experienced designer serving as a project engineer may be concerned about meeting internal budget criteria as well as meeting the client's needs. A less-experienced designer working at a lower level of responsibility may consider the opportunity to gain valuable design experience as a success criteria and be less concerned about meeting the internal budget.

No single list will ever be totally comprehensive when it comes to a definition of success for a project. The criteria developed for use with the CPSF project does give a general overall impression of each of the three groups viewpoints. It determines the "envelope" of ideas that are used to evaluate success.

Critical Success Factors

Critical success factors are defined as those factors predicting success on projects. In the literature, several authors identified, explained, and discussed the factors that are critical to the success of a project.

> Those few things that must go well to ensure success for a manager or organization, and therefore, they represent those managerial or enterprise areas that must be given special and continual attention to bring about high performance. Critical Success Factors include issues vital to an organization's current operating activities and its future success [Boynton and Zmund (1984)].

> They are events or circumstances that require the special attention of management because of their significance to the corporation. They may be internal or external and be positive or negative in their impact. Their essential character is the presence of a need from special aware-

ness or attention to avoid unpleasant surprises or missed opportunities or objectives. They may be identified by evaluating corporate strategy, environment, resources, operations [Ferguson and Dickinson (1982)].

Those few key areas of activities in which favorable results are absolutely necessary for a particular manager to reach his or her goals [Rockart (1982)].

The manuals, articles, and papers describing previous work in critical project success factors (CPSFs) vary in content and quality, and indicate differences in focus of the studies. Approximately 20 sources (research papers and theses) were collected and reviewed for the present research. The literature covers a variety of project industries, including computer software development projects and shipbuilding. This body of literature represents a significant contribution to our understanding of project success factors and criteria. However, much uncertainty remains in need of clarification.

Examples of issues not yet adequately resolved are: (1) What CPSFs are valid for building construction? In previous research the focus was not on building construction, and in fact building construction formed a minority of the projects studied. (2) Are the same or different factors important for different types of buildings, e.g. hospitals versus office buildings? (3) In reports that included successful-unsuccessful project pair studies, the judgment whether the project was successful or unsuccessful was based on one participant only. It seems unlikely that other project participants would necessarily have the same judgment of the project. And (4) all of the previous studies based their hypothesized CPSFs on experiential and anecdotal evidence. Are there no theories available that could form the basis of a more rigorous approach to the CPSF problem?

Basis for Factors—IBPM

Given these shortcomings of previous research efforts, the writers searched for a theoretical basis for the factors. A process model, the integrated building process model (IBPM), had been developed to identify all major functions required to provide a facility and the information that is produced and utilized by each function (Sanvido et al. 1990). The model was developed

Sub-Category: PRODUCT INFORMATION		M	P	D	C	O
FACILITY IDEA		i/o	c			
PLANNING INFORMATION	Program		o	i		
	Site Information		o	i		
	Project Execution Plan		o	i	i	i
	Facility Planning Knowledge		o	i		
DESIGN INFORMATION	Bid Construction Documents and Criteria			o	i	
	Operations and Maintenance Documents			o		i
	Facility Design Knowledge			o	i	
CONSTRUCTION INFORMATION	Post Construction Documents				o	i
	Facility Construction Knowledge				o	i

i - Input to the Function   o - Output of the Function

FIG. 1. Product Control Elements and Their Relationships to Five Major Functions in Model

Sub-Category	Element	M	P	D	C	O
CONTRACTS, CHANGES, AND OBLIGATIONS	Facility Plan	o	c			
	Design Plan	o		c		
	Construction Plan	o			c	
	Operation Plan	o				c
	Contract(s): Planning Contract	o	c			
	Design Contract	o		c		
	Construction Contract	o			c	
	Operation Contract	o				c
FACILITY TEAM	Facility Champion	m				
	Management Team	m				
	Planning Team	o	m			
	Design Team	o		m		
	Construction Team	o			m	
	Operation Team	o				m
FACILITY EXPERIENCE	Facility Mamangement Experience	o				
	Facility Planning Experience		o			
	Facility Design Experience			o		
	Facility Construction Experience				o	
	Facility Operation Experience					o
RESOURCES	Planning Resources	o	i			
	Design Resources	o		i		
	Construction Resources	o			i	
	Operation Resources	o				i

i - Input to the Function   o - Output of the Function

c - Constraint on the Function   m - Mechanism for the Function

FIG. 2. Process Control Elements and Their Relationships to Five Major Functions in Model

Sub-Category	Element	M	P	D	C	O
OPTIMIZATION INFORMATION	Designability Information	c		o		
	Constructability Information	c			o	
	Operability Information	c				o
PERFORMANCE INFORMATION	Planning Performance Information	c	o			
	Design Performance Information	c		o		
	Construction Performance Information	c			o	
	Operations Performance Information	c				o

c - Constraint on the Function

o - Output of the Function

FIG. 3. Feedback Elements and Their Relationships to Five Major Functions in Model

to four hierarchical levels of detail from data collected on 22 building projects. It was drawn from the perspective of the owner of the facility.

The IBPM identifies elements of information and physical entities that must flow between the manage (M), plan (P), design (D), construct (C), and operate (O) functions. [The reader is directed to (Sanvido et al. 1990) for a full description of the IBPM.] These elements are grouped into nine subcategories (Sanvido 1990). Figures 1–3 show the elements of the subcategories and their relationship to the M, P, D, C, and O functions. The elements that form the basis for the questionnaire are all defined as follows.

The facility team is assembled by the owner to provide the facility. This team starts with the facility champion and expands to include representatives

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of the planner, designer, constructor, owner, operator, consultants, and facilities managers.

The contract, obligations, and changes category covers all the written or verbal agreements and changes to them that are used among different parties during the various phases of the project.

Facility experience is the information and knowledge that results from providing the facility that is not included as formally communicated documents but is resident in other media, e.g. company history and project participants' memories. This improves the abilities of the members of the facility team to provide similar or related facilities in the future. The elements of this category are management experience, planning experience, design experience, construction experience, and operation experience.

Resources includes all resources provided for the facility by all participants (money, time and man-hours, permanent materials and equipment, energy, information, equipment, temporary materials, tools, and the workplace or site).

Product information comprises the information elements used to describe and communicate that the facility is in various stages of development. These elements are transformed from the facility idea and the site through the planning information (project execution plan, program and site information, etc.), the design information (design documents, bid documents, etc.), the constructed facility, and from construction information to the operational facility.

Optimization information is the information used to integrate expertise of participants in providing the facility. This includes designability, constructability, and operability information.

Performance information is information about the progress of activities that, when compared to the plan, is interpreted to assess the status of the project and the appropriateness of the plan.

Constraints are parameters or variables that hinder, limit, or impact the participants in their ability to provide a facility.

Products are the physical building–related "noninformational" outputs of specific functions, which can be inputs or control elements for other functions in the model. The key physical products are defined as the site, the constructed facility, and the operational facility.

Research Methods

Questionnaire

A questionnaire was developed to facilitate data collection by the researchers and to ensure consistency in the elements examined. The questionnaire (see a sample page in Fig. 4) was separated by each major function, viz management, planning, design, construction, and operation. Each of these sets of questions has two parts. The first part determines the closeness of fit of the functions as performed on the project with the ideal or modeled functions just defined. There are nine major categories of questions. The second part determines the degree of success that the responding participant experienced on the given project.

The questions are thus classified by function and not by the people who carry them out. For each project, the people who perform these functions will be different depending on the contract type, the phase of the project, local regulations and so on. Therefore, the same set of questions may be

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Asked:	Manager	Company:
Category:	Facility team	Project:
Elements:	Planning Team	**RANKING - Bad, Unsatisf., Good, Very Good, Excellent**
	Design Team	Quality of element:
	Construction Team	Timeliness of element:
	Operation Team	Cost effectiveness:
		Impact on success:

QUESTION	REPLY	FACTORS/CRITERIA TO CHECK FOR
How do you select the people for the planning, design, construction and operation phases? Planning Design Construction Operation		capabilities of the team understanding of the staff needs availability contract type chemistry
Were the following three items, team selection, project needs, and the contract strategy developed together? How?		communication company policies contract types

FIG. 4. CPSF Question and Answer Summary Sheet

directed to more than one person for each project. The data will be collected from the individuals who perform the five basic functions of the model.

The questions are nonleading, and are structured so that the interviewee would not be biased and answer freely, given the relatively short list of questions. Each question is accompanied by a set of items that must be examined in the answers. These items are based on the literature search and are intended to aid in refining the replies and comparing the information obtained from different interviewees.

Selection of Projects

To analyze the data meaningfully, the writers carefully selected eight pairs of projects. The two projects in each pair were similar in scope and proposed by the same sponsor. One project was successful in the eyes of the sponsor and the second was less successful. To compare projects in a given field, three categories were established. These categories all included projects in which there were significant M, P, D, C, and O functions to be performed. An ideal project fell in the range of 100,000–200,000 sq ft (9,467–18,935 m^2) in area, but some projects were larger. The categories selected were: (1) Owner-occupied, lease-equivalent space (O), e.g. office and retail buildings; (2) high-tech, high-reliability buildings (H), e.g. lab facilities and hospitals; (3) multiphase projects in which the occupant is in the building (R), e.g. renovation work and multiphase buildings.

A summary of the projects together with their reference numbers is as follows.

- Sponsor 1—Projects H1, H2, R1, R2
- Sponsor 2—Projects O1, O2, H3, H4
- Sponsor 3—Projects O3, O4, H5, H6
- Sponsor 4—Projects H7, H8
- Company 5—Projects O5, O6

Note that sponsor four was only able to provide two sites. The researchers then solicited another company to provide a pair of projects to study. The first letter of these project numbers refers to the type of facility, the second to a sequential series. These project numbers are constant for the remainder of the paper.

Data Collection Procedure

In preparation for a site visit, the researchers reviewed all pertinent information available on the project. This included a completed project-data form and any literature provided by the sponsor company. After scheduling the site visit and immediately upon arrival, the researchers met the principal players and toured the site (where possible) to become familiar with the project.

The chief purpose of the site visits was to determine which agencies/companies were responsible for performing each of the five key functions. Where more than one agency/company performed a given function, responses were collected from both companies. Interviews proceeded in the sequence in which the project was executed; i.e., with the owner, architect, engineer, contractor, and operator. Where applicable, the researchers obtained physical evidence of key techniques used to accomplish a task. All answers were cross-checked with other participants.

At the conclusion of each interview the interviewee was asked to rank how successful that project was. The interviewee was also asked to determine whether that function had either a positive or negative effect on the project's success, and what that effect was. Also, researchers solicited input on lessons learned on that project and what had been done to implement those lessons in subsequent projects.

Data-Reduction Procedure

The data collected from each project were recorded directly on the questionnaire. These data were reduced onto the data analysis sheet (Figs. 5 and 6). Given this sheet, two data descriptions were prepared.

The first type was a verbal description of the information on each project provided under the following headings: facts, functions, and lessons learned. The facts section defined the project background and description of the building, the key players and contracts, and cost and schedule data. The functions section defined how the facility team, contracts, facility experience, resources, product information, optimization information, and performance information were performed or achieved. The final section listed the lessons learned for each principal player.

A second type of data reduction was the conversion of the questionnaire data to a numerical system. This is presented in detail later in this paper. Sample results of the textual information follows.

Sample Descriptive Results for Two Projects

Project Number O1

Facts

Background and description: New operations center, data processing center [400,000 sq ft (37,870 m²)] built in northeastern U.S., built on a new site. Raised floor, modular electrical wiring system, uninterrupted power supply (UPS), emergency power, halon systems, universal wiring system, access floor, security systems, sound masking, heat recovery.

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Sub-Category	Element	Evidence of Elements
FACILITY TEAM	Management Team Planning Team Design Team Construction Team Operation Team	
CONTRACTS, CHANGES, OBLIGATIONS	Management Contract/ Plan Planning Contract/ Plan Design Contract/ Plan Construction Contract/ Plan Operation Contract/ Plan	
FACILITY EXPERIENCE	Facility Management Experience Facility Planning Experience Facility Design Experience Facility Construction Experience Facility Operation Experience	
RESOURCES	Management Resources Planning Resources Design Resources Construction Resources Operation Resources	
PRODUCTS	Site Constructed Facility Operational Facility	
PRODUCT INFORMATION	Facility Idea Planning Information/ Program Design Information Construction Information	
EXTERNAL	External Factors Owner's Home Office Planner's Home Office/ Subs Designer's Home Office/ Subs Constructor's Home Office/ Subs	
OPTIMIZATION INFORMATION	User's Information Designability Information Constructability Information Operability Information	
PERFORMANCE INFORMATION	Project Performance Information Planning Performance Information Design Performance Information Construction Performance Information Operations Performance Information	

FIG. 5. Data Analysis Sheet 1

Key players: Project managed by owner and developer; design by architect with specialty subs (negotiated lump sum); construction manager [cost plus fixed fee with a guaranteed maximum price (GMP)]; in-house building operator.

Design start: 9/89.

Construction: 11/88 to 4/89.

Final construction cost at turnover: $45 million.

Functions

Facility team: The owner had little experience and selected a project developer to assist him in this task. A participative management style was employed, which ensured a good team. The construction manager (CM) was hired at the same time as the architect.

Contracts: The architect and design team had fixed-fee contracts. The

SUCCESS CRITERIA	Manager Planner Designer Constructor Operator	
SUCCESS	Manager Planner Designer Constructor Operator	
LESSONS LEARNED		

FIG. 6. Data Analysis Sheet 2

fee was tied to the principals of the key designers' staying with the company for the duration of the project. The contracts all allowed the participants to function as a team.

Experience: The developer had experience in this area, but it was the largest such facility done by them. The mechanical/electrical designer had had a very similar project before this one. The design team had experience working together.

Resources: The CM's previous job suffered from insufficient staff. On this project the project executive made sure that the staffing level was correct.

Product information: The architect employed a team-building program to develop a common frame of reference, program, and philosophy on the project. The coordination using an overlay drafting system on the project was unsatisfactory. The contractor lost momentum due to frequent changes.

Optimization information: The contractor provided good value engineering (VE) input. The team had to work to change the philosophy of the operator.

Performance information: The user's chief executive officer (CEO) was involved in weekly reviews. Good control.

External constraints: Unusual spells of dry and wet weather and sinkholes constrained the contractor. The owner's home office staff changed their minds on the size of the facility. The windows that were supplied did not meet the design specification.

Product: Good.

Success: Generally the most successful job in all the companies.

Lessons Learned

Owner: Remove weak team members as soon as possible. Clearly state all assumptions in the design phase and ensure that the client knows and understands what they are. Hold multiple contracts with all key designers; don't have one contract with an architect only.

Architect: Educate the owner and community on what quality of building they get for their funds. Take tours of similar facilities to communicate the space and quality of finishes.

Engineers: Spend the time to get to know the project manager. Spend time up front developing the team.

Contractor: Used the same organization and staffing levels on subsequent projects successfully.

Project Number O2

Facts

Background and description: New corporate office headquarters [110,000 sq ft (10,414 m^2)] built in the northeastern U.S. on an urban restricted site. Structural steel frame, self-contained air conditioning (AC) with roof-mounted dry cooler, and automated control system. Masonry walls with brick facade.

Key players: Project managed by owner and consultant project manager; design by architect with specialty subs (negotiated lump sum); construction manager (cost plus fixed fee with a GMP); in-house operator.

Design start: 4/86.

Construction: 9/88 to 10/89.

Final construction cost at turnover: $12 million.

Functions

Facility team: The owner brought in a project manager to assist them. The project manager had no authority, and dragged out key project decisions. There was a large amount of friction between the project manager, architect, and mechanical designer. The project management team changed during the project. The new project manager was abusive, and the team could not function well.

Contracts: The architect's and the mechanical designer's fees were cut drastically by the owner. A GMP construction contract was developed with very poor documentation.

Experience: The owner had no experience and the project manager had very little experience. The operator had absolutely no experience, and at the time of the site visit, the project had its third operator.

Resources: Available.

Product information: The owner had many changes of mind because the large committee representing the owner later in the project had been left out in the earlier phases. The architect had to revise the program done by another architectural firm. The GMP documents were incomplete, but construction documents were fairly good.

Optimization information: The owner was brought in too late to the process and made scope changes. The contractibility input by the contractor

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was poor. It was hypothesized that the contractor had a vested interest in keeping the budget low until they were required to guarantee the price. No operability input was received.

Performance information: The absence of quality control was the only deficiency in this category.

External constraints: The site size and height restrictions severely limited the building. Severe changes from the owner's home office impacted the project.

Product: Poor site and poor operations of facility.

Success: Average to poor.

Lessons Learned

Owner: Hard to work with an architect located off site. Must have a good on-site project manager. Must have high-level people involved in the project. A precise delegation of authority is essential.

Architect: The owner's decision-making cycle must be quick and responsive. Resist a project manager and work for structured owners. Pay the fee requested.

Engineer: Insist on user-groups involvement during the design phase.

Contractor: Evaluate subcontractors and material suppliers at the end of the project. Panelize as much millwork as possible on projects of this type.

Numerical Results

The data obtained from the questions is transferred onto a data analysis sheet (Figs. 5 and 6) for each project. The data analysis sheet requires the researcher to evaluate the quality of each major element being performed for each of the five project participants identified.

Thus, each subcategory, e.g. facility team, has five possible elements. These elements represent the teams provided to manage, plan, design, construct, and operate the facility. To rank the quality and timeliness of the element associated with a particular project function, there must be agreement from the parties questioned and physical evidence, where possible, regarding the existence, timeliness, and quality of the subject subelement. For example, in evaluating the planning information or program, the researcher would check the response of the planner and designer, since the program flows from the planner to the designer.

Fig. 7 provides a numerical representation of the data collected from the projects. The top section of the figure indicates the closeness of fit to the ideal situation predicted by the model; the lower section represents the participants' views of project success. The product category indicates participant's views of the building end product as a physical item; the success indicators define the broader project issues such as profit, meeting objectives, and reputations.

The values for such subcategory in the left-hand column of the upper section of Fig. 7 are derived as follows. The manager, planner, designer, contractor, and operator are all ranked as either 0 or 1 for each element of the subcategory. A 0 means that everything was performed correctly; a 1 indicates that this function was below average or not performed. The numbers are then added for each sub category to give the indicated score (shown in Fig. 7 as a single entry). A low score of 0 indicates good performance; a high score of 5 indicates poor performance. The variable at the bottom of the upper section, "CFIT," indicates the closeness of fit to the modeled

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FUNCTION						PROJECT NUMBER										
SUBCATEGORY	H1	H2	R1	R2	O1	O2	H3	H4	O3	O4	H5	H6	O5	O6	H7	H8
Facility team	1	3	3	3	0	3	1	3	0	0	1	2	1	1	0	5
Contracts	0	1	0	1	0	3	0	1	2	1	1	0	3	1	0	0
Experience	0	1	0	4	0	2	0	2	1	0	1	2	2	1	0	0
Resources	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0
Product Info	0	1	1	1	1	2	1	2	1	1	1	2	1	1	1	0
Optimization Info	0	2	0	2	0	3	1	2	3	1	2	2	2	1	0	2
Performance Info	1	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1
CFIT	2	9	4	11	1	14	3	10	7	4	8	9	11	6	1	8
External	3	2	3	2	3	2	1	3	2	2	3	4	3	1	1	1
Products	0	0	0	0	0	2	0	0	2	1	1	1	0	0	0	2
SUCCESS																
Manage	5	4	4	2	5	4	5	4	4	5	3	3	2	4	5	4
Plan	3	3	4	5	5	3	4	5	4	5	4	3	3	4	5	5
Design		3			5	1	4	1	3	5	4	2	3	4	5	4
Construct	4	3	5	2	5	3	4	2	4	5	5	4	4	3	5	3
Operate									3	5	2	2	4	4	4	3
SUM ALL	12	13	13	9	20	11	17	12	18	25	18	14	16	19	24	19
NO ALL	3	4	3	3	4	4	4	4	5	5	5	5	5	5	5	5
SUM MDC	12	10	13	9	15	9	13	9	11	15	11.5	9	10	11	14.5	11
SALL	0.80	0.65	0.87	0.60	1.00	0.55	0.85	0.60	0.72	1.00	0.72	0.56	0.64	0.76	0.96	0.76
SMDC	0.80	0.67	0.87	0.60	1.00	0.60	0.87	0.60	0.73	1.00	0.77	0.60	0.67	0.73	0.97	0.73

FIG. 7. Success Factor Data for 16 Projects

functions for the whole project. A low score is 0 (excellent) and the maximum score is 35 (worst case).

The calculation of CFIT did not include data from the two question subcategories "External" (constraints) and "Products," which are included as two separate line items. External constraints describe factors beyond the control of the project team, not functions performed. Products describe the satisfaction of the respective players with the facility. These two were included in the questions to aggregate these comments and separate them from the required subcategory data.

The lower section of Fig. 7, titled "SUCCESS," measures the participant's success ranking of the project. The ranking scale for success is as follows: 1 = very unsuccessful; 2 = poor; 3 = average; 4 = better than average; and 5 = outstanding. In some cases success rankings could not be collected, and these fields in the figure are left blank.

The numbers at the bottom in the row "SALL" are a weighted percentage rating given the success ratings. The second number, "SMDC," is developed using a combined manage and operate score; a combined planning and design score; and a construction score; each weighted as three equals. In both cases ("SALL" and "SMDC") 1.0 indicates a very successful job, and 0 indicates a very unsuccessful project.

SALL and SMDC are calculated as follows:

$$\text{SALL} = \frac{\text{SUM ALL}}{\text{NO ALL} \cdot 5} \quad \text{(1)}$$

$$\text{SMDC} = \frac{\text{SUM MDC}}{3 \cdot 5} \quad \text{(2)}$$

where NO ALL = number of success responses used in the calculation.

Analysis of Results

Several types of analysis are discussed. First, projects are grouped into pairs of similar buildings. Both projects in each pair were proposed by a common sponsor company. The results are analyzed to determine whether projects that were closer to the modeled structure were more successful than those that were further from the model. Second, all projects examined by each data collector were summarized, their closeness of fit to the model, and performance were ranked and correlated. Third, all projects were grouped by type for a similar analysis. A fourth analysis of all projects studied was performed and the results correlated. All four analyses used the following procedure.

1. Rank the closeness of fit (CFIT) of each project in each group (see "CRANK," in Fig. 8).
2. Rank the success (SMDC) of each project in each group (see "SRANK," in Fig. 8).
3. Compute Spearman's rho between rankings in steps 1 and 2

$$\text{rho} = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} \qquad (3)$$

where d = difference between the CFIT and SMDC ranks for each of the cases in the given group; and n = number of cases in the group being ranked. Results are presented in Fig. 8.

FUNCTION							PROJECT NUMBER									
SUBCATEGORY	H1	H2	R1	R2	O1	O2	H3	H4	O3	O4	H5	H6	O5	O6	H7	H8
Facility team	1	3	3	3	0	3	1	3	0	0	1	2	1	1	0	5
Contracts	0	1	0	1	0	3	0	1	2	1	1	0	3	1	0	0
Experience	0	1	0	4	0	2	0	2	1	0	1	2	2	1	0	0
Resources	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0
Product Info	0	1	1	1	1	2	1	2	1	1	1	2	1	1	1	0
Optimization Info	0	2	0	2	0	3	1	2	3	1	2	2	2	1	0	2
Performance Info	1	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1
CFIT	2	9	4	11	1	14	3	10	7	4	8	9	11	6	1	8
External	3	2	3	2	3	2	1	3	2	2	3	4	3	1	1	1
Products	0	0	0	0	0	2	0	0	2	1	1	1	0	0	0	2
CRANK PAIR	1	2	1	2	1	2	1	2	2	1	1	2	2	1	1	2
CRANK SPONSOR	1	3	2	4	1	4	2	3	2	1	3	4	4	2	1	3
CRANK TYPE	2	6	1	2	1	6	3	8	4	2	4	6	5	3	1	4
CRANK ALL	3	11	5	14	1	16	4	13	8	5	9	11	14	7	1	9
SUCCESS																
Manage	5	4	4	2	5	4	5	4	4	5	3	3	2	4	5	4
Plan	3	3	4	5	5	3	4	5	4	5	4	3	3	4	5	5
Design		3			5	1	4	1	3	5	4	2	3	4	5	4
Construct	4	3	5	2	5	3	4	2	4	5	5	4	4	3	5	3
Operate									3	5	2	2	4	4	4	3
SUM ALL	12	13	13	9	20	11	17	12	18	25	18	14	16	19	24	19
NO ALL	3	4	3	3	4	4	4	4	5	5	5	5	5	5	5	5
SUM MDC	12	10	13	9	15	9	13	9	11	15	11.5	9	10	11	14.5	11
SALL	0.80	0.65	0.87	0.60	1.00	0.55	0.85	0.60	0.72	1.00	0.72	0.56	0.64	0.76	0.96	0.76
SMDC	0.80	0.67	0.87	0.60	1.00	0.60	0.87	0.60	0.73	1.00	0.77	0.60	0.67	0.73	0.97	0.73
SRANK PAIR	1	2	1	2	1	2	1	2	2	1	1	2	2	1	1	2
SRANK SPONSOR	2	3	1	4	1	3	2	3	3	1	2	4	4	2	1	2
SRANK TYPE	3	6	1	2	1	6	2	7	3	1	4	7	5	3	1	5
SRANK ALL	6	11	4	13	1	13	4	13	8	1	7	13	11	8	3	8
d sponsor	1	0	-1	0	0	-1	0	0	1	0	-1	0	0	0	0	-1
Rho sponsor				0.8				0.9				0.8				0.9
d type	1	0	0	0	0	0	-1	-1	-1	-1	0	1	0	0	0	1
Rho	rhoH	0.94	rhoO	0.94	rhoR	1										
d all	3	0	-1	-1	0	-3	0	0	0	-4	-2	2	-3	1	2	-1
Rho all	0.91															

FIG. 8. Analysis of Success Factors for 16 Projects

Pairwise Analysis

In this section, projects are grouped into pairs of similar buildings. Both projects in a pair were proposed by a common sponsor company. The results are analyzed to determine whether projects that were closer to the modeled structure were more successful than those that were further from the model.

The pairs selected for comparison were H1 and H2; R1 and R2; O1 and O2; H3 and H4; O3 and O4; H5 and H6; O5 and O6; and H7 and H8. "CRANK PAIR" and "SRANK PAIR" indicate the ranking of CFIT and SMDC, respectively, for each pair. In all cases, the project that had a higher score for CFIT (see Fig. 8) was the poorer performer as indicated by SMDC. The rho for each project was 1.0, indicating perfect correlation.

Analysis by Sponsor

The following five groups of projects with the same sponsor were analyzed.

- Sponsor 1) Projects: H1, H2, R1, and R2
- Sponsor 2) Projects: O1, O2, H3, and H4
- Sponsor 3) Projects: O3, O4, H5, and H6
- Sponsor 4) Projects: O5 and O6
- Sponsor 5) Projects: H7 and H8

For each sponsor, the CFIT and SMDC scores were ranked and correlated. Spearman's rho was calculated for each group, and the results are shown in Fig. 8. In all cases rho was 0.8 or higher—this indicates excellent correlation (rho $>$ 0.5 indicates significance and rho $>$ 0.75 indicates excellent correlation).

Analysis by Type of Project

The projects all belonging to the H, O, and R groups were analyzed and ranked accordingly. Rho H, rho O, and rho R were all above 0.94 and showed excellent correlation by project type—which was expected.

Analysis of All Projects

When all projects were analyzed together, the resulting rho was 0.901. This indicates that the testing method and critical success factors are applicable to all projects studied.

Comment on Results

All four methods of analysis showed that projects closer to the modeled structure or those where the elements of the function subcategories were properly performed enjoyed better success for all parties than those projects further from ideal. This held true for project pairs, those proposed by the same sponsor, those in the same industry market segment, and for all projects analyzed together. This correlation indicates that the seven function subcategories and their 35 elements are indeed project success factors.

When examining Fig. 8, the reader can infer the relative importance of the success factors. The facility team; contracts, changes, and obligations; facility experience; and optimization information varied significantly between successful and unsuccessful projects. These four factors can then be deemed the critical project success factors (CPSFs).

One factor, the product information (i.e., design documents and the

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coordination of the discipline during the design phase), was a problem on both poor and good jobs. In general, projects with good teams, contracts, experience, and optimization input were able to work around incomplete drawings and program changes. Those with poorly functioning teams could not react to this condition. Two other factors had lesser significance on the project. The supply of resources by the members of the team was generally good, and no instances were found in which they were significantly restricted. Performance information was found to be formally provided in the construction and operational phases, but informally provided in the planning and design phase (due to the small design teams). Quality control by the general contractor was the most common deficiency.

The results of the research indicated that there were seven success factors. Of these seven, four were found to be critical: (1) A well-organized, cohesive facility team to manage, plan, design, construct, and operate the facility. Team chemistry was typically developed by common goals and activities. (2) A series of contracts that allows and encourages the various specialists to behave as a team without conflicts of interest and differing goals. These contracts must allocate risk and reward in the correct proportions. (3) Experience in the management, planning, design, construction, and operations of similar facilities. And (4) timely, valuable optimization information from the owner, user, designer, contractor, and operator in the planning and design phases of the facility.

Areas for Further Research

Research often uncovers new questions in the process of providing answers to previously asked questions. Several topics in this work also need further refinement: (1) The research showed by analysis of the data that the listed factors are significantly present in the projects considered most successful. The CPSFs should also be tested on one or more projects to determine if project success is guaranteed by the mere presence of these factors. (2) There is a need to systematically develop procedures to ensure the successful performance of each factor. (3) To develop a predictive model the financial impacts of the absence of the CPSFs should be studied and compared with the cost of achieving the CPSFs on a project. With this information the optimum level of CPSFs may be predicted for a given project. And (4) this study focused on 16 projects from a select industry category. Further research is needed to conclusively test these CPSFs.

Conclusions

The initial objectives of this research were to define the critical factors that lead to project success and provide a forecasting tool to enable parties to rapidly assess the possibility of a successful project from their viewpoint. These general objectives were met through the accomplishments of the research. More importantly, a list of specific factors were identified as critical to the success of projects.

The topic of this research required a critical look at projects that were deemed less successful by their nominators, thus creating potential embarrassment to those involved or noncooperation with the research. The research team was able to avoid this danger successfully; made possible by the excellent cooperation and support the Consortium for the Advancement of Building Sciences (CABS) members provided. Other participants in the projects also displayed a remarkable spirit of cooperation and genuine interest in the successful outcome of the research. Under these conditions the writers were able to bring the project to successful conclusion.

The research team set out to study CPSFs applicable to building projects, based on established theoretical work in construction process modeling. The research was successful in identifying a number of CPSFs based on extensive field research on 16 selected construction projects. Clearly, some questions await further study. Although more projects are necessary to provide conclusive evidence, this work provided significant insight into the essential elements of project success.

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