CRITICAL SUCCESS FACTORS FOR DIFFERENT PROJECT OBJECTIVES

By D. K. H. Chua,[1] Member, ASCE, Y. C. Kog,[2] and P. K. Loh[3]

ABSTRACT: The identification of key factors for construction project success enables appropriate allocation of limited resources. Most of the related past work only identified critical success factors for construction projects in general. The present study seeks to distinguish these factors according to the project objectives of budget, schedule, and quality. The analytic hierarchy process is adopted to determine the relative importance of success-related factors. A hierarchical model for construction project success is presented. Sixty-seven success-related factors are considered. These factors are grouped under four main project aspects, namely, project characteristics, contractual arrangements, project participants, and interactive processes in the hierarchical model for project success. A questionnaire was developed to facilitate systematic data collection in this study. Experts with an overall average of 20 years of experience in the construction industry were invited to participate in the survey. Critical success factors addressing budget performance, schedule performance, quality performance, and overall project success are identified. Some pertinent findings of the study are discussed. Comparisons with findings of previous studies using neural network approach are also presented.

INTRODUCTION

It is generally accepted that the major goals in a construction project are budget, schedule and quality, although there are other more specific objectives, such as safety consideration and market entry, depending on the nature of the project and company. A variety of factors determine the success or failure of projects in terms of these objectives. The identification of the critical success factors (CSFs) for these objectives will enable limited resources of time, manpower, and money to be allocated appropriately. Some researches have been conducted to identify CSFs for project success using quantitative measures of various factors (Jaselskis and Ashley 1991; Chua et al. 1997; Kog et al., unpublished paper, 1999). However, these factors are only confined to the project management efforts. The same approach also cannot be adopted to cover intangible factors or be used when hard performance data are not available.

Alternatively, CSFs can also be identified based on expert opinions. The impact of experience possessed by project key personnel toward project outcomes has been widely recognized (Jaselskis and Ashley 1991; Sanvido et al. 1992). It would be legitimate then to assume that experienced practitioners would have composed a set of CSFs after testing against their experience. Invariably, two approaches have been employed to capture expert opinions in a few previous surveys on project success. In the first approach, the respondents were asked to identify a list of factors that they thought were critical and then to indicate their subjective importance of these factors (Pinto and Slevin 1987). In this approach it is difficult to ensure that the factors identified by the respondents are consistent in nomenclature and scope. Alternatively, the respondents were given a list of factors and asked to assess the influence of these factors based on a scale determined by Chan and Kumaraswamy (1997). Using this approach, it also is not possible to ensure consistency in the assessment when there are more than a few factors.

[1]Assoc. Prof., Dept. of Civ. Engrg., Nat. Univ. of Singapore, Singapore 119260.

[2]Executive Dir., Beca Carter Hollings & Ferner (SEAsia) Pte. Ltd., Anson Centre, Singapore 079904.

[3]Res. Scholar, Dept. of Civ. Engrg., Nat. Univ. of Singapore, Singapore 119260.

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The present study seeks to identify the CSFs for construction projects, based on accumulative knowledge and judgment of experts in the industry. The analytical hierarchy process (AHP) is adopted to solicit consistent subjective expert judgment. The AHP procedure developed by Saaty (1980) has been widely used for multicriteria decision making. In this study a hierarchical model for construction project success is presented, where success is determined by a variety of factors pertaining to four main project aspects, namely, project characteristics, contractual arrangements, project participants, and interactive processes. Altogether, 67 factors were examined. Through a survey with experts from leading construction-related organizations, the CSFs for the objectives of budget, schedule, and quality are identified.

FACTORS RELATED TO CONSTRUCTION PROJECT SUCCESS

The investigation on project success has attracted the interest of many researchers and practitioners. Baker et al. (1983) reported the result of a survey pertaining to project success. Although the survey was not focused on construction activities, and the variables considered leaned toward conceptual strategies, the results nonetheless provide a good starting point for studying the more specific CSFs for construction projects. The CSFs for construction projects identified by Sanvido et al. (1992) were also broad strategic principles, which would definitely require further refinement to identify lower level factors that can be implemented as project strategies.

Nahapiet and Nahapiet (1985) made a comparative study on the building construction practice in the United States and United Kingdom with particular reference to the managerial and organizational aspects of the projects. A more detailed investigation on the relationships between project execution strategies and project performance can be found in the works of Jaselskis and Ashley (1991) and Alarcon and Ashley (1996). They recognized the primary role of the project management team as planning, executing, and coordinating the project.

There were other studies conducted on specific aspects of construction projects. These included project partnering (Larson 1995), the influence of management and labor on construction productivity (Lim 1993), the success of the traditional building process (Mohsini and Davidson 1992), construction contracting methods (Gordon 1994), as well as contract disputes (Diekmann and Girard 1995). There were also works on project management success instead of success of the project as a whole (Might and Fisher 1985; Pinto and Slevin 1987). Despite their emphasis on a limited facet of project success, these works undoubtedly contribute to the overall success model.

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TABLE 1. Success-Related Factors Considered in Present Study

Project aspect (1)	Success-related factor (2)
Project characteristics	(1) Politcal risks; (2) economic risks; (3) impact on public; (4) technical approval authorities; (5) adequacy of funding; (6) site limitation and location; (7) constructability; (8) pioneering status; (9) project size
Contractual arrangements	(10) Realistic obligations/clear objectives; (11) risk identification and allocation; (12) adequacy of plans and specifications; (13) formal dispute resolution process; (14) motivation/incentives
Project participants	(15) PM competency; (16) PM authority; (17) PM commitment and involvement; (18) capability of client key personnel; (19) competency of client proposed team; (20) client team turnover rate; (21) client top management support; (22) client track record; (23) client level of service; (24) Capability of contractor key personnel; (25) competency of contractor proposed team; (26) contractor team turnover rate; (27) contractor top management support; (28) contractor track record; (29) contractor level of service; (30) capability of consultant key personnel; (31) competency of consultant proposed team; (32) consultant team turnover rate; (33) consultant top management support; (34) consultant track record; (35) consultant level of service; (36) capability of subcontractors key personnel; (37) competency of subcontractors proposed team; (38) subcontractors team turnover rate; (39) subcontractors top management support; (40) subcontractors track record; (41) subcontractors level of service; (42) capability of suppliers key personnel; (43) competency of suppliers proposed team; (44) suppliers team turnover rate; (45) suppliers top management support; (46) suppliers track record; (47) suppliers level of service
Interactive Processes	(48) Formal design communication; (49) informal design communication; (50) formal construction communication; (51) informal construction communication; (52) functional plans; (53) design complete at construction start; (54) constructability program; (55) level of modularization; (56) level of automation; (57) level of skill labors required; (58) report updates; (59) budget updates; (60) schedule updates; (61) design control meetings; (62) construction control meetings; (63) site inspections; (64) work organization chart; (65) common goal; (66) motivational factor; (67) relationships

The CSFs identified in the various studies range from general conceptual guidelines (Baker et al. 1983; Pinto and Slevin 1987; Sanvido et al. 1992) to more specific execution strategies (Jaselskis and Ashley 1991). It would be difficult, if not impossible, to compare the relative significance of these factors at different levels of focus. Therefore, the success-related factors are organized in a hierarchical project success model in the present study. In this way, meaningful comparisons can be made among the factors at the same level. The list of success-related factors included in the model is shown in Table 1. Many of these factors have been abstracted from previous studies and arranged under four main project aspects, namely, project characteristics, contractual arrangements, project participants, and interactive processes.

Most of the past work has only identified the CSFs for project success in general. In reality, the various factors contribute differently to different project objectives (Jaselskis and Ashley 1991). Pursuant to the AHP approach, the contribution of the factors toward the three main objectives of budget, schedule, and quality can be determined and separate lists of CSFs can be identified.

AHP

AHP is a procedure suited for complex technological, economic, and sociopolitical decision making (Saaty and Vargas 1991). Pursuant to this approach, a problem is separated into a hierarchy with the goal at the top (Level 1). Level 2 of the hierarchy comprises the main criteria to achieve the goal, and subsequent levels consist of elements with increasing degree of detail. For the present study, project success is the goal. The objectives of budget, schedule, and quality are three criteria to achieve the goal. The success-related factors are grouped within the appropriate subcriteria for evaluation. The hierarchical model for construction project success will be presented in the following section. Such a hierarchical representation would enhance the understanding of the problem. Furthermore, the pairwise comparison procedure to determine the significance of a set of factors at level i with respect to the immediate next higher element at level $i - 1$ has the advantage of focusing exclusively on two factors at a time. Although it generates more information than is really necessary, the extra information can be used to maintain the consistency in the judgments (Saaty 1980).

The pairwise comparisons are guided by a nine-point scale as depicted in Table 2. Adopting the nine-point scale, the experts would be able to express their judgment subjectively. Hence it is possible to make comparisons between tangible and intangible factors. The computation of the relative importance of the factors using the eigenvalue and eigenvector of the pairwise comparisons matrix is briefly presented in Appendix I.

TABLE 2. Pairwise Comparison Scale [Adapted from Saaty (1980)]

Level of importance (1)	Definition (2)
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Very strong or demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between adjacent scale values

The AHP's systematic approach in soliciting an expert's judgment and a consistency check have also made it a reliable way to determine the priorities to a set of factors, which may then be incorporated into other evaluation systems. For example, Paek et al. (1992) adopted the AHP method to determine the relative weights of the criteria in a fuzzy-logic system for the selection of design/build proposals. The work by Dozzi et al. (1996) and Pocock et al. (1996) also employed the method in a similar fashion. The present study exploits the AHP method to weigh the relative importance of success-related factors to identify the CSFs among them.

HIERARCHICAL MODEL FOR CONSTRUCTION PROJECT SUCCESS

A typical construction project environment, particularly under the traditional procurement method with separate consultants and a contractor, can be simplified as depicted in Fig. 1. It embraces the four main aspects of a construction project, namely, project characteristics, contractual arrangements, project participants, and interactive processes involving the project participants (i.e., communication, project planning, control, and project organization). The contribution of project execution strategies (modeled herein mainly as interactive processes) toward project success has been widely recognized (Jaselskis and Ashley 1991; Alarcon and Ashley 1996). However, the project characteristics, contractual arrangements, and project participants, which are virtually unchanged once the project has started, will appreciably influence the appropriateness

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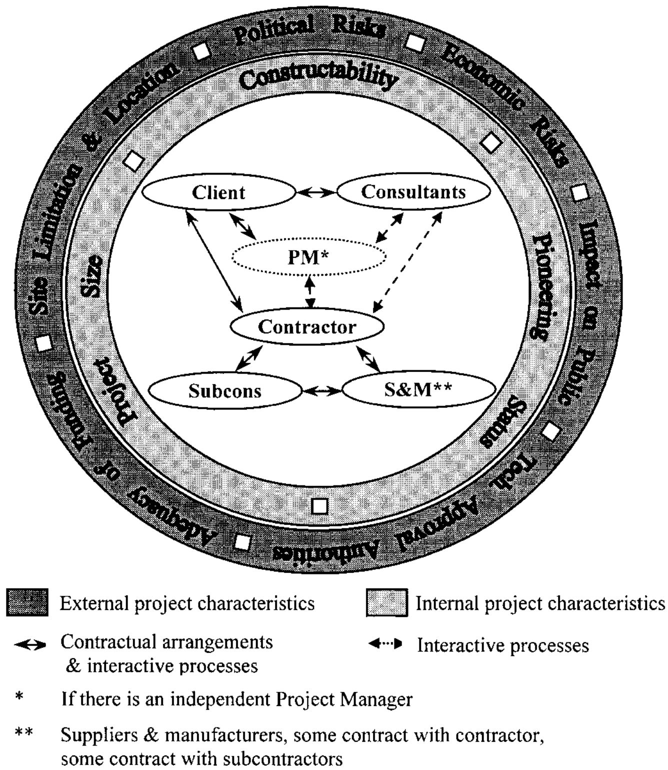

FIG. 1. Typical Construction Project Environment

of the implementation strategies and hence the project outcome. Therefore, these predetermined aspects of a project should not be ignored in the success model.

A hierarchical model for construction project success can be established based on the typical project environment, as shown in Fig. 2. At the top of the hierarchy is the goal of ''construction project success.'' The objectives of budget, schedule, and quality that contribute to the goal occupy the second level of the hierarchy. In this arrangement the success-related factors occupying the lower tiers of the hierarchy can be considered in three different contexts. The four main project aspects occupy the immediate lower level. Each of the success-related factors will occupy the lower level of the subhierarchy corresponding to one of those four project aspects.

There are two major reasons for grouping the success-related factors under separate subhierarchies. First, factors of similar nature should logically be grouped into one cluster to facilitate pairwise comparisons during the survey. Second, it is known that an individual cannot simultaneously compare more than 7 ± 2 elements with satisfactory consistency and hence hierarchical decomposition is desirable (Saaty and Vargas 1991).

Project Characteristics

Diekmann and Girard (1995) observed that project characteristics might contribute to certain project risks, including financial risks and schedule delays. Hierarchically, project characteristics can be further divided into external and internal characteristics. The former is associated with the surrounding environment that includes factors such as political and economical risks (Hadipriono and Chang 1988), impact on public (Diekmann and Girard 1995), efficiency of technical approval authorities (Baker et al. 1983; Macomber 1989), adequacy of funding (Baker et al. 1983; Macomber 1989), and site limitation and location (Macomber 1989; Diekmann and Girard 1995). Internal project characteristics, on the other hand, are inherent to the project, such as constructability, pioneering status, and project size (Diekmann and Girard 1995). A project is considered as a ''pioneering'' project if its technology is new to the project team.

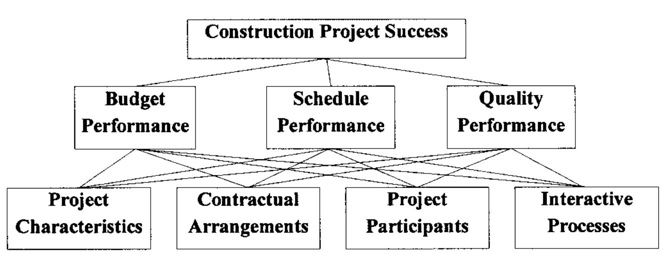

FIG. 2. Hierarchical Model for Construction Project Success

Contractual Arrangements

Sanvido et al. (1992) identified proper contractual arrangements as a CSF for construction projects. In the present study, the factors grouped under this project aspect are not focused on detailed implementation issues such as contract type (i.e., lump-sum, reimbursable, or guaranteed-maximum-price) (Macomber 1989) or contract award method. Instead, emphasis is placed on major considerations that lead to the above implementation issues. One main consideration in contractual arrangement is the identification of risk and its equitable allocation (Gordon 1994; Diekmann and Girard 1995). This will dictate both the content and the type of the contract. Adequacy and clarity of plans and technical specifications also contribute to this end. Furthermore, any form of contractual relationship ought to be founded along with consideration of realistic obligations and clear objectives. The provision for a formal resolution process in case of disputes is another consideration. The aspect of contractual arrangements should also include motivation and incentives to the contracting parties.

Project Participants

Mohsini and Davidson (1992) maintained that interorganizational conflicts in a construction project will adversely affect project performance. Attributes of project participants, therefore, cannot be overlooked. Project participants refer to the key players, namely, the project manager (PM), client, contractor, consultants, subcontractors, and suppliers and manufacturers. The present study adopted the following definition of PM offered by Jeffery (1985): ''the person who is effectively in charge of the project and has sufficient authority, personality, and reputation to ensure that everything that needs to be done for the benefit of the project is done.'' Effective project management will depend on the PM's competency and authority (Jaselskis and Ashley 1991). The PM's involvement and commitment is also crucial for project success, and this can be affected by the number of projects that the PM manages at the same time. It is reasonable to suggest that these attributes of a PM are relevant to project success regardless of the organization to which the PM is directly affiliated (i.e., client, contractor, consultant, or independent project management provider) and the country in which the project is constructed. This is because the bottom-line consideration of a PM should be ''benefiting the project'' rather than ''protecting the employer's interest.''

The active participation and cooperation of the other key players depend significantly on the capability of the key personnel and the overall competency of the team assigned to the project. Furthermore, the level of support from top management (Pinto and Slevin 1987) in their respective organizations is a factor that can determine the ease and the will to resolve difficulties that arise. Team turnover rate (Jaselskis and Ashley 1991), track record (Macomber 1989), and the level of service

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that the organization is obliged and willing to deliver are the other attributes considered. Hierarchically, these factors can be arranged as shown in Fig. 3(a).

Interactive Processes

A study by Larson (1995) suggests that project success can be better assured if owner and contractor firms can work together as a team with established common objectives and defined procedures for collaborative problem solving. Similar working relationships should be extended to include all project participants. Toward this end, interactive processes play an important role. For the present study, interactive processes refer to the communication, planning, monitoring and control, and project organization to facilitate effective coordination throughout the project life.

Communication concerns the adequacy of communication channels, both formal and informal, and their effectiveness to provide sufficient information on project objectives, status, changes, organizational coordination, client's needs, current problems, etc. to the appropriate project members (Pinto and Slevin 1987). Project planning refers to the importance of developing various detailed plans over the whole project life cycle (Pinto and Slevin 1987). The key issues considered in project planning may include preparation of functional plans (Zall et al. 1994), percent of design complete at construction start (Jaselskis and Ashley 1991), implementation of a constructability program (Jaselskis and Ashley 1991; Construction 1991), level of modularization (Jaselskis and Ashley 1991), level of automation, and level of skill labors required. Monitoring is essentially concerned with observing and reporting (feedback) on actual performance against expected progress, whereas control involves taking action to influence future events with the aim of achieving what has been laid down on plan (Nahapiet and Nahapiet 1985). Project organization deals with the question of whether the project organizational environment is conducive for mutual operation. Apart from the work organization chart (Zall et al. 1994), other factors worth

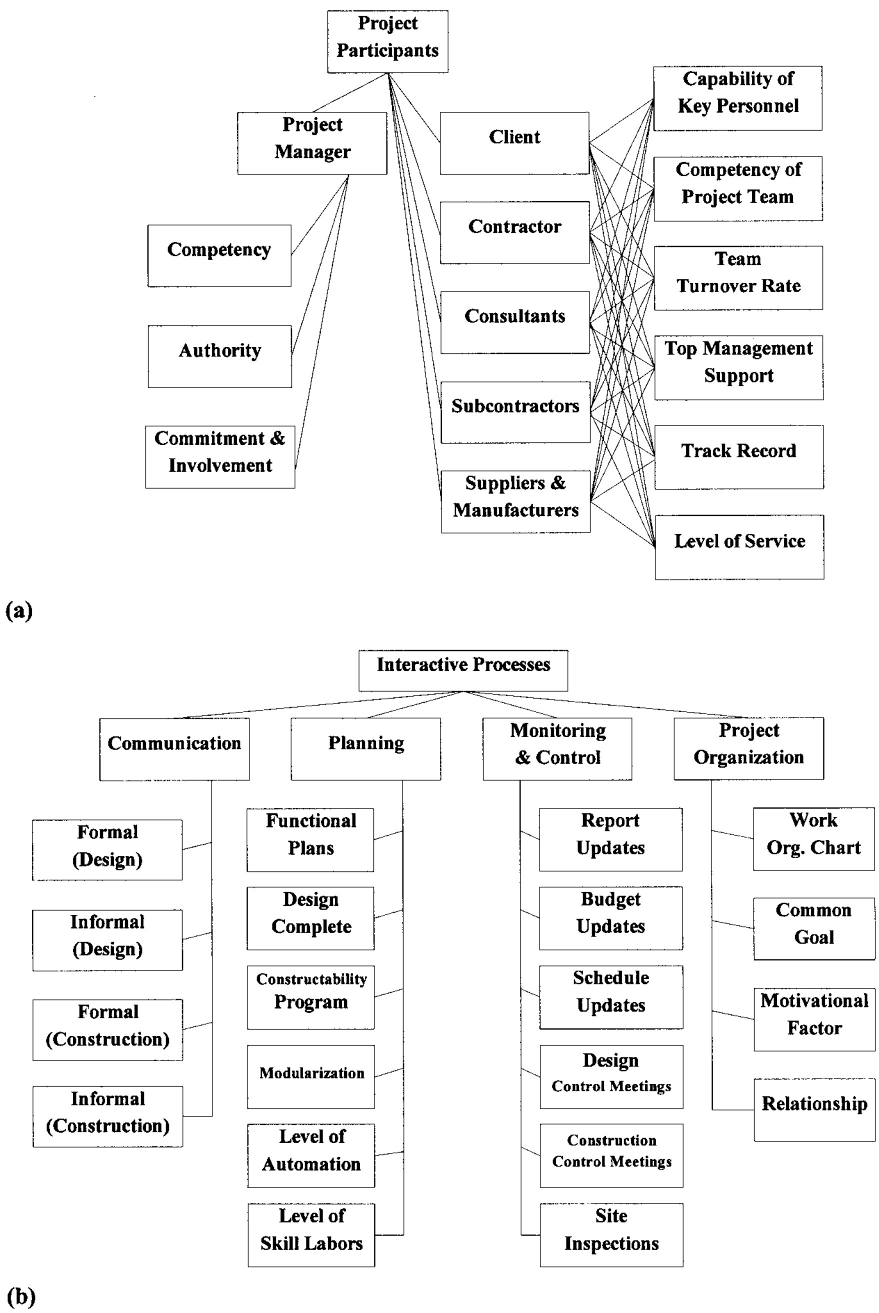

FIG. 3. Subhierarchy for: (a) Project Participants; (b) Interactive Processes

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considering are common goal of project participants (Baker et al. 1983; Larson 1995), availability of motivational factors other than contractual incentives, and business relationships among the project participants (Diekmann and Girard 1995). Fig. 3(b) shows the subhierarchy for interactive processes.

RESEARCH SETTING AND SAMPLE

A questionnaire was developed to facilitate systematic data collection. Apart from some questions intended to capture background information of the respondents, the remaining questions in the questionnaire invite the respondents to consider the relative importance of a pair of success-related factors at each time, based on the nine-point scale summarized in Table 2. Throughout the questionnaire, the concept of importance is interpreted in a generic way and is comparable to preference, dominance, and similar relationships. To ensure consistency throughout by the respondents, the definition of the factors has been provided. The questionnaire was designed in a manner that will help in the preservation of integrity and consistency in the data. The questions relating to different project aspects are presented in different sections. This will help the respondents to focus on one project aspect at a time. In each section, the respondents begin by comparing factors at the bottom level of the subhierarchy. This bottom-to-top approach will assist the respondents to apprehend the collective significance of lower level factors as they proceed upward in the construction project success hierarchy.

From many experienced practitioners contacted, 20 were willing to participate in the study. All respondents are currently holding senior managerial positions in leading private construction companies or consultant firms in Singapore or are serving in statutory boards (public organizations) responsible for development of public projects. They have an average of 20 years of experience in the industry. Half of the respondents have worked mainly as consultants. Five respondents gained their experience mainly through working with contractor organizations. The remaining respondents spent most of their career path with project clients or project management organizations.

The relatively small sample size is mainly attributed to two reasons. First, only those with about 15 years of experience would be approached to preserve the quality of the opinions gathered in the survey. This has significantly reduced the pool size of the potential respondents. Second, some of the experienced practitioners contacted were reluctant to participate in the survey because of the commitment expected from them, bearing in mind that they have to make pairwise comparisons of 67 success-related factors across three project objectives. Although the size of the sample is relatively small, the knowledge and judgments of the respondents are accumulated over construction projects too numerous to mention and, therefore, would be reasonably reflective of the consensus of the construction industry.

To secure good quality data, a brief presentation with regard to the object and methodology of the study was made to every respondent individually. The respondents were specifically reminded of the importance of observing consistency in their answers. They were made to understand that their responses should not be biased toward any particular project whether it was highly successful or disastrous.

The data were analyzed using *Expert Choice* (1996), a software package that incorporates AHP on a microcomputer. A second meeting was conducted with the respondents individually for the purpose of refining their judgments, where necessary, to achieve satisfactory consistent weights (consistency ratio of <0.1).

RESULTS AND DISCUSSIONS

This section discusses some of the pertinent findings of the study. The Kendall's sampling distribution test, which is approximated by the χ^2 distribution when more than seven factors are being considered, reveals significant positive association between the rankings of the respondents (Yeomans 1979). The calculated χ^2 values for the association of the respondents' rankings in terms of budget performance, schedule performance, quality performance, and overall success are 591.8, 465.3, 388.9, and 478.9, respectively. The relevant critical value for χ^2 at 0.95 confidence level is 87.0. Therefore, it is legitimate to take the average of the weights assigned by the respondents as reflective of the relative importance of the respective factors. The findings reported in the paper are based on the average weights of the factors, unless otherwise stipulated.

The relative importance of the three objectives of construction project success is presented in Table 3. Although schedule performance was ranked as most important, their relative weights were comparable. In other words, none of the success objectives can be sacrificed, and equal importance should be accorded to each of them.

CSFs

The ranking of the top ten CSFs for each project objective is presented in Table 4. Evidently, each set of CSFs differs depending on the project objective. Nonetheless, adequacy of plans and specifications, and constructability emerge prominently as the two most CSFs regardless of project objective. Adequacy of plans and specifications will significantly reduce the uncertainties during tender submissions or other contractual negotiations and hence minimize project risks. A high level of constructability may reflect minimal start-up difficulties and amount of rework (Baker et al. 1983). Furthermore, many of the CSFs were identified from categories pertaining to project characteristics and contractual arrangement. These are the prime concerns during the feasibility and planning phases, and they have an appreciable bearing on implementation strategies during construction.

PM competency, and PM commitment and involvement have also been identified as CSFs for all objectives of project success but at different levels of significance. There are some CSFs that are peculiar to each success objective. As expected, economic risks, adequacy of funding, and budget updates are considered as important only for budget performance. On the other hand, the schedule updates factor is crucial for schedule performance. The third most important factor in ensuring quality performance was identified as site inspections. Other CSFs peculiar to quality performance include formal communication during construction and design control meetings.

The top five CSFs according to the organizational backgrounds of the respondents are also presented in Table 4. It can be seen that although respondents with dissimilar organizational background rank the factors differently, most of the top five CSFs are within the top-ten list based on the average weights of all respondents. It is interesting to note that respondents who had mainly been involved in project management in their career have identified PM authority as the most important CSF regardless of project objectives. Although it is

TABLE 3. Relative Importance of Different Project Objectives

Success objectives (1)	Relative importance (2)
Budget performance	0.314
Schedule performance	0.360
Quality performance	0.325

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TABLE 4. Ranking of CSFs for Different Project Objectives

Success-related factor (1)	Av (2)	Organization Type O1 (3)	O2 (4)	O3 (5)	O4 (6)	Av (7)	Organization Type O1 (8)	O2 (9)	O3 (10)	O4 (11)
	Budget performance					Schedule performance				
Adequacy of plans and specifications	1	1	1	1	3	1	2	3	2	—
Constructability	2	3	4	2	—	2	4	5	1	—
Economic risks	3	4	—	3	2	—	—	—	—	—
Realistic obligations/clear objectives	3	—	2	—	5	6	—	1	3	3
PM competency	5	2	—	—	4	4	1	—	—	2
Adequacy of funding	6	5	—	—	—	—	—	—	—	5
Budget updates	7	—	3	—	—	—	—	—	—	—
PM commitment and involvement	8	—	—	—	—	3	5	—	—	—
Contractual motivation/incentives	9	—	5	—	—	5	3	—	—	4
Risk identification and allocation	10	—	—	3	—	—	—	—	—	—
Political risks	—	—	—	4	—	—	—	—	—	—
PM authority	—	—	—	—	1	—	—	—	—	1
Schedule updates	—	—	—	—	—	7	—	2	5	—
Construction control meetings	—	—	—	—	—	8	—	4	—	—
Capability of contractor key person	—	—	—	—	—	9	—	—	—	—
Site inspections	—	—	—	—	—	10	—	—	—	—
Pioneering status	—	—	—	—	—	—	—	—	4	—
	Quality performance					Overall				
Adequacy of plans and specifications	1	1	2	1	4	1	2	1	2	4
Constructability	2	3	3	3	5	2	3	3	1	—
Site inspections	3	4	4	2	—	7	—	—	5	—
PM commitment and involvement	4	—	—	—	—	3	5	—	—	—
Realistic obligations/clear objectives	5	—	1	5	2	4	—	2	3	3
PM competency	6	2	—	—	3	4	1	—	—	2
Construction control meetings	7	—	5	—	—	8	—	—	—	—
Formal communication (construction)	8	—	—	—	—	9	—	—	—	—
Capability of contractor key person	9	—	—	—	—	—	—	—	—	—
Design control meetings	10	—	—	—	—	—	—	—	—	—
Contractual motivation/incentives	10	—	—	—	—	6	4	4	—	—
Pioneering status	—	5	—	—	—	—	—	—	—	—
PM authority	—	—	—	—	1	—	—	—	—	1
Supplier level of service	—	—	—	3	—	—	—	—	4	—
Economic risks	—	—	—	—	—	9	—	—	—	5

Note: Av = average rank; O1 = consultant; O2 = contractor; O3 = client; O4 = project management.

interesting to analyze the results based on the organizational backgrounds of the respondents, the differences reported here are by no means conclusive in view of the small sample size after grouping the respondents accordingly. Further research is necessary before more meaningful conclusions can be drawn.

Project Characteristics

The relative importance of external project characteristics is presented in Fig. 4(a), with the weights normalized so that the most important factor is given a unit value. The two finance-related factors (i.e., economic risks and adequacy of funding) are identified as most important for budget performance. On the other hand, efficiency of technical approval authorities, and site limitation and location are two factors considered important for schedule and quality performances but at different levels of significance. Efficiency of technical approval authorities, being the major concern for schedule performance, may be attributed to statutory regulations requiring various approvals to be obtained prior to the commencement of work on site. In the context of quality performance, the most important factor is site limitation and location. This factor determines, among others, the viable construction methods and availability of resources that are closely linked to the quality of work on site.

Table 5 presents the relative importance of internal project characteristics. The relative importance of the three internal project characteristics seems to follow a similar trend across the three project objectives: constructability is identified as most important, followed by pioneering status, and then project size. The great influence of project constructability seems to have outweighed the collective impact of pioneering status and project scale.

Contractual Arrangements

The relative importance of the elements of contractual arrangements is shown in Fig. 4(b). Adequacy of plans and specifications has been considered as the most significant CSF for all three project objectives. A possible explanation for this may be that plans and technical specifications contained in the contract document generally provide the basis for contractors' tender price as well as resource procurement and allocation strategy. Plans and specifications also delineate client's expectation with respect to the quality of the final product. The above discussions are also relevant to the contractual arrangements between contractors and subcontractors as well as suppliers.

Another important consideration in contractual arrangements for all three project objectives is realistic obligations and clear objectives. Ward et al. (1991) maintained that whatever objectives are set in contracts, there is a need for a realistic level—otherwise contracting parties will not be fully motivated to achieve them or may lead to adversarial interparty relationship. For satisfactory schedule performance, it also seems important to include some motivational schemes or incentives in the contractual arrangements.

Project Participants

The relative importance of project participants is presented in Fig. 4(c). The PM has been ranked first among the project

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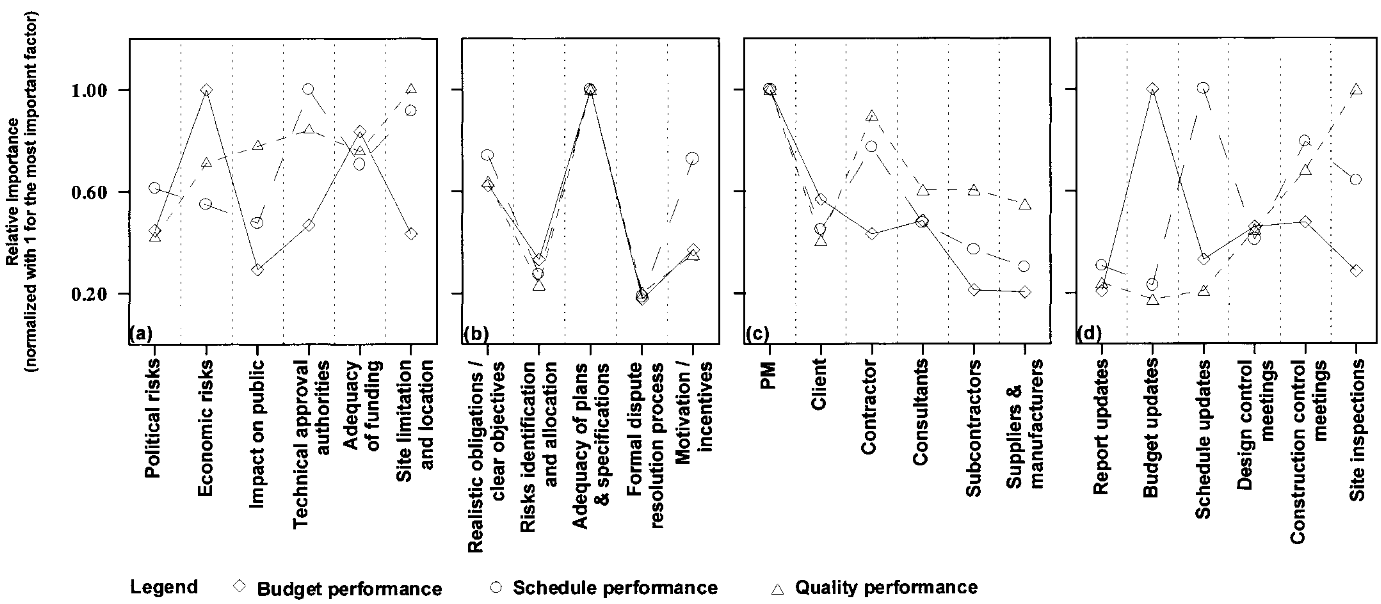

FIG. 4. Relative importance of: (a) External Project Characteristics; (b) Contractual Arrangements; (c) Project Participants; (d) Elements of Monitoring and Control

TABLE 5. Relative Importance of Internal Project Characteristics (Normalized with 1 for Most Important Factor)

Internal project characteristics (1)	Relative Importance: Budget performance (2)	Schedule performance (3)	Quality performance (4)
Constructability	1.000	1.000	1.000
Pioneering status	0.322	0.354	0.385
Project size	0.258	0.285	0.304

participants for all project objectives. Furthermore, the client seems to have more influence on budget performance than in schedule or quality performance of a project. The contractor has been identified as the second most critical participant in the context of schedule and quality performances.

With respect to the participants' attributes, the capability of the key personnel assigned to the project has been identified as the most important factor. The other two important attributes are competency of the proposed team and top management support from their respective organizations. The track record of the organization has been considered as having the least influence in governing project success. This suggests it is more important to ensure that the project participants assign their experienced personnel from past successful projects to work on the current one.

Interactive Processes

Table 6 shows the relative importance of the factors under interactive processes. The monitoring and control factor has been identified as most significant in this regard, for all project objectives. This is especially so for quality performance. It is important to establish a monitoring and feedback mechanism to ensure that any unexpected problem can be dealt with promptly and effectively. The planning function plays a lesser but significant role to ensure good budget and schedule performances.

Fig. 4(d) presents the relative importance of the elements within the scope of monitoring and control. The budget updates factor has been considered the most important factor for budget performance. Similarly, schedule updates are important

TABLE 6. Relative Importance of Interactive Processes (Normalized with 1 for Most Important Factor)

Interactive processes (1)	Relative Importance: Budget performance (2)	Schedule performance (3)	Quality performance (4)
Communication	0.507	0.408	0.502
Planning	0.866	0.796	0.443
Monitoring and control	1.000	1.000	1.000
Project organization	0.426	0.349	0.349

TABLE 7. Comparison of CSFs for Budget and Schedule Performances with Previous Studies (Confined to Factors Related to Project Participants and Interactive Processes)

Budget Performance: Present study (1)	Chua et al. (1997) (2)	Schedule Performance: Present study (3)	Kog et al. (unpublished paper, 1999) (4)
PM competency	✓	PM competency	✓
Budget updates	✓	PM commitment and involvement	✓
PM commitment and involvement		Schedule updates	
Design complete at construction start	✓	Construction control meetings	
Formal communication during design		Capability of contractor key personnel	
PM authority	✓	Site inspections	
Constructability program	✓	Formal communication during construction	
Formal communication during construction		Constuctability program	✓
Construction control meetings	✓	PM authority	
Design control meetings		Competency of contractor proposed team	

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for schedule performance, whereas site inspections are important for quality performance. In addition, the results also suggest that the control meetings during construction factor is relatively more important than meetings during design phase, for all three project objectives. This again reflects that construction activities are not something that can be fully ''preplanned.'' Instead, project success depends highly on the commitment of the parties during the construction phase.

Comparison with Previous Studies

Chua et al. (1997) and Kog et al. (unpublished paper, 1999) identified the CSFs for construction budget and schedule performances, respectively, using a neural network approach. The potential CSFs considered in the studies covered 27 factors related to the PM, project team, planning, and control effort. These factors are confined to measurable factors, and the data were based on completed projects in the United States. In the present study, these factors have mainly been considered either explicitly or implicitly in the aspects of project participants and interactive processes. The 10 CSFs in these aspects for budget and schedule performances identified in the present study are compared with those of the previous studies in Table 7.

Chua et al. (1997) identified eight CSFs for budget performance. As shown in Table 7, six of them are also found to be important in the present study. The other two factors identified previously are project team turnover rate and control system budget. The former has been outweighed by the capability of key personnel from respective participating organizations in the present study, which was not considered previously. The latter is not considered in the present study as the construction practice in Singapore does not normally allocate a separate amount of expenses, particularly for control system.

The CSFs for schedule performance identified in the present study were also found to be consistent with Kog et al. (unpublished paper, 1999), in which five CSFs are identified. PM commitment and involvement in the present study embraces two CSFs identified previously, namely, time devoted by the PM and the frequency of meetings the PM held with other project personnel. This effectively means that four out of five CSFs identified previously have also been found important in the present study. The fifth CSF identified by Kog et al. (unpublished paper, 1999) is monetary incentives provided to the designer. This factor is within the scope of motivation in contractual arrangements considered in the present study, which is one of the CSFs for schedule performance as shown in Table 4.

In essence, the comparison using two distinct approaches suggests that the AHP method is a feasible approach to identify the CSFs. In addition, this approach allows both tangible and intangible factors to be considered in the study. It is also interesting to note that, as far as project participants and interactive processes are concerned, the CSFs identified based on inputs from two different geographical areas exhibit a very high degree of similarity.

CONCLUSIONS

The present study has adopted the AHP method to identify CSFs for construction projects. A hierarchical model for construction project success is presented. Results of the study reveal that experts do agree that there are different sets of CSFs for different project objectives. The findings show that project characteristics and contractual arrangements cannot be left out of the success equation. In other words, project success is not determined exclusively by the PM, monitoring, and control efforts. In summary, the plausibility of project success can be increased if inherent characteristics of the project can be thoroughly understood, appropriate contractual arrangements are adopted, competent management team is assigned, and sound monitoring and control system is established.

The CSFs identified in this study were found to be consistent with those determined in a previous study using a neural network with quantitative data. The AHP method is not only viable to identify CSFs but it allows intangible factors to be considered as well.

Further research can be carried out with fewer success-related factors being considered after discarding those factors identified as less important in the present study. This would increase the number of experts who are willing to participate in the survey as less time would be required of them to complete the questionnaire. With a greater number of respondents, more meaningful comparisons can be made by analyzing the results according to organizational backgrounds of the respondents, types of project, etc. Similar research may also be conducted with respect to construction activities in other countries, using the present findings as the basis for research framework and comparison.

APPENDIX I. COMPUTATION OF RELATIVE IMPORTANCE

To obtain the relative importance of the factors, the numerical weights obtained from pairwise comparisons can be arranged into a matrix form

$$\mathbf{A} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 & \cdots & w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 & \cdots & w_3/w_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & w_n/w_3 & \cdots & w_n/w_n \end{bmatrix} \quad (1)$$

where w_x/w_y = relative importance of factor x compared to factor y in the same set in level i; and n = number of factors in the set being compared with respect to an element in level $i - 1$.

The matrix of pairwise comparisons ($\mathbf{A}$) can then be cast into an eigenvalue problem

$$\mathbf{A} \cdot \mathbf{W} = \mathbf{n} \cdot \mathbf{W} \quad (2)$$

where $\mathbf{W} = (w_1, w_2, \ldots, w_n)^T$ = vector of relative weights. In matrix algebra, $\mathbf{n}$ and $\mathbf{W}$ are termed the eigenvalue and the eigenvector of A, respectively. In this way, the relative weights of the factors, $\mathbf{W}$, can be evaluated from the eigenvalue problem of (2) when the matrix $\mathbf{A}$ of relative importance judgments has been solicited.

As a result of some inconsistencies in their judgment, experts normally fail to produce the pairwise comparisons matrix $\mathbf{A}$ accurately (Zahedi 1986). Instead, a consistency ratio can be computed from the solution of the eigenvalue problem. It has been established that a consistency ratio of 0.1 or less is considered acceptable (Saaty 1980). This is another distinct feature of the AHP, which makes it a very appealing ranking tool; a characteristic that is lacking in other approaches dealing with subjective ranking.

If the problem hierarchy consists of more than two levels, the overall priority of one factor with regard to the goal is the successive product of the relative weights obtained at each level. In this sense, the final priority vector reflects the relative importance of the factors with respect to project success. It is worth mentioning here that if factor X has a final importance of 0.10 and factor Y has a final importance of 0.05, then X is not only more important in some vague sense but is twice as important as Y.

APPENDIX II. REFERENCES

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