A PRACTICAL LIST OF CRITERIA FOR EVALUATING CONSTRUCTION PROJECT SUCCESS IN DEVELOPING COUNTRIES

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Abstract

Project success is a difficult concept because of the project's complexity and dynamic. It is discussed a long time by many researchers. Until now, there is no accepted universal definition of project success, but no one can disclaim the importance of evaluating project success, especially in construction. Project success is a foundation to manage and control the current project, plan and orient the future project. In this paper, a practical list of criteria for evaluating project success is discussed. The final proposed framework is the result of both academic and practical point of view, from the solid foundation of literature review to the actual completed project information and document collected. The final indexes and sub-indexes in this list had to satisfy three criteria, which are high capacity to collect information, high level of importance, and high degree of applicability to evaluate project success. To achieve this objective, two surveys were performed. The first survey collected information from twenty-eight completed projects to consider the capacity to collect necessary information to evaluate project success. The second survey gathered opinions from sixty-five respondents about the importance level and applicability level of each index and sub-index. From analysis results, seven sub-indexes were eliminated from the list. The final list of criteria included eleven indexes which were clearly described by forty six sub-indexes.

Keywords: Construction success, Project success, Success criteria, Success evaluation

Introduction

The Concept of Project Success and Construction Project Success

Project success is a difficult concept because of the project's complexity and dynamic. Until now, there is no accepted universal definition of project success. Definition of project success may vary depending on each industry, project team, or individuals' point of views (Parfitt and Sanvido 1993). It is different among participants, scope of services, project size, and time-dependent (Shenhar and Levy 1997). "An architect may consider success in terms of aesthetic appearance, an engineer in terms of technical competence, an accountant in terms of dollars spent under budget, a human resources manager in terms of employee satisfaction, and a chief executive officers rate their success in the stock market" (Freeman and Beale 1992 cited in Shenhar and Levy (1997)). However, according to Parfitt and Sanvido (1993), project success definition is different for each participant, but it is based on the basic concept of the overall achievement of project goals and expectations. These goals and expectation includes technical, financial, educational, social, and professional issues.

Shenhar and Levy (1997) provided a definition of project success from Cleland (1986) that “Project success is meaningful only if considered from two vantage points: the degree to which the project’s technical performance objective was attained on time and within budget, and the contribution that the project made to the strategic mission of the enterprise.”

De Wit (1988) provided a definition of project success as “the project is considered an overall success if the project meets the technical performance specification 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.”

Liu and Walker (1998) defined project success at two levels. The first level is project’s goals concerning time, budget, functionality/quality/technical specification, safety and environmental sustainability. The second level is the satisfaction of the claimant(s).

In the construction industry, the concept of project success varies among different projects depending on participants, project size, scope of services, and the time required to implement a project. Nevertheless, there are common threads across the industry concerning the perceptions and expectations of the designer, owner, or contractor. Contractor selection is an important event for project success. The purpose of all models which are studied to select contractors is to help the owner achieve project success. Therefore, project success can be considered as a reflection to evaluate how good the contractor selection process is.

So far it is still difficult to get an agreement on the concept of project success. As discussed above, it depends on many factors, especially human perceptions. The concept of “project success score” is developed specifically for this research. “Project success score” is a quantifiable number that can represent the level of project success when the project is completed, how well the project outcome is compared with proposed project objectives. This concept can be used to assess and compare the completed projects, which are in the same category of project type, project scale, and capital type. Future projects can benchmark against previous projects.

In order to achieve “project success score”, a complete framework of project success evaluation should be studied. In the scope of this paper, a practical list of criteria for evaluating project success will be discussed.

Distinction between Project Success - Project Management Success, Success Criteria – Success Factors

A distinction should be made between project success and project management success. They are often confused, but they are not the same. De Wit (1988) showed many examples from their research on about 650 completed projects in the USA, and concluded that “a project can be a success despite poor project management performance and vice versa”. They stressed that “good project management can contribute towards project success but is unlikely to be able to prevent project failure” (De Wit 1988). Project management plays an important role in project success, but there are many factors which are out of direct control which may affect project success. Project management is considered successful if it satisfies a number of requirements. They include effective planning, the involvement of a skillful project manager, adequate time to define a project thoroughly, correct planning, reliable and sufficient information flows, changing activities to adapt to frequent changes in the project, meeting employees' expectations regarding performance and rewards, and identifying mistakes in project implementation in order to make timely adjustments (Munns and Bjeirmi 1996). From this narrow definition of successful project management, it is believed that the concept of project success encompasses more than project management success, and they are not directly correlated.

According to Oxford Advanced Learner's Dictionary, criterion means "a standard or principle by which something is judged, or with the help of which a decision is made"; whereas a factor is "one or several things that cause or influence something". So, the concept of "project success criteria" and "project success factor" are different, but sometimes they are misunderstood. From this definition, a set of criteria project success establishes the groundwork of project success judgement. It includes a set of standards or principles which are used to judge the project. On the other hand, project success factors are the set of several things that cause or influence project outcomes, which contribute to the project success or failure.

Up to this time, most studies have focused on project success factors. These published articles include Sanvido *et al.* (1992), Hatush and Skitmore (1997), Chan *et al.* (2001), Chan *et al.* (2004), Chu *et al.* (2004), Nguyen *et al.* (2004), Salminen (2005), Chan *et al.* (2010), and Tabish and Jha (2011). Chua *et al.* (1999) suggested a set of sixty-seven factors related to project success and categorized them in four groups which were project characteristics, contractual arrangements, project participants, and interactive processes.

It is important to stress that, the concept used in this paper is the project success criteria. The criteria will be described as the set of indexes and sub-indexes of project success. Again, this research will not focus on what factors influence or contribute to project success or failure. It completely concentrates on the principles or standards by which the project is judged.

A Literature Review of Project Success Measurement

The problem of whether the project success can be measured or not has been addressed by many researchers a long time ago. From De Wit (1988), measuring success is complex because it depends on the stakeholders' points of view and it is time dependent. A project can be perceived as a success for one party but a failure for another. De Wit (1988) believed the concept that "one can objectively measure the success of a project is an illusion". Nevertheless, he pointed out that it is possible and valuable to evaluate project at the post-completion stage. He also provided evidence, the Project Management Institute conference help in Montreal in 1986, to demonstrate the possibility of success measurement. The purpose of this conference was to examine the importance of good measurement indicators of project success. It received the earlier version of papers related to "measuring success" implying a message that project success is possible to determine.

Result measure, process measure, and relationship measure are three types of measures of the partnering in the construction industry (Crane *et al.* 1999). All of them are important and strong in their proper place. Among them, result measure is the most difficult to evaluate, but it is the most useful for future strategy adjustments. According to the proposed objective of this research, from this point forward, project success is considered at the completed stage.

This section will consider the measurement of project success proposed by previous researches in order to develop a construction project evaluation system. From the literature review, the problem of project success measurement was considered in three aspects which are the list of indicators and criteria in measurement, the methodology to assess each index and sub-index and responsible parties, the important weight of each index and sub-index, and the methods to combine them.

The first group of researchers created a solid foundation for this study when they described the whole picture of project success measurement index (De Wit 1988; Songer *et al.* 1997; Liu and Walker 1998; Crane *et al.* 1999; Lim and Mohamed 1999; Tukel and Rom 2001; White and Fortune 2002; Bryde and Robinson 2005; Ahadzie *et al.* 2008; Al-Tmeemy *et al.* 2011). They collected the indexes from previous researches or industry and then asked the perception of respondents. Most of them were based on the importance scale to evaluate the important level of each. These studies provided a good reference. However, these researchers have not carried out the applicability or information that is used to gather the capacity of these indexes. Furthermore, each study is developed based on one party's point of view such as owners, contractors, or project managers.

Project objectives are the most appropriate criteria for project success. The success or failure of a project is determined based on the degree to which these objectives are being met. From De Wit (1988), the criteria for project success are restricted to time, cost, and quality. He also discussed the results on construction project success from a pilot study at the University of Texas. According to the results, construction project success is frequently measured by six criteria including budget performance, schedule performance, and project stakeholders' satisfaction.

A list of six criteria for success was developed from Songer *et al.* (1997). They are 'On budget', 'On schedule', 'Meets specifications', 'Conforms to user's expectations', 'High quality of workmanship', and 'Minimizes construction aggravation'. 'On budget' refers to the completion of project within the contracted cost. 'On schedule' means this completion is achieved prior to or on the date as shown in the contract. 'Meets specifications' suggests the ability to meet or exceed the entire owner's provided specifications of technical performance. 'Conforms to user's expectations' is the ability to meet or exceed the envisioned functional goals of the user (fitness for purpose). Finally, an ability to meet or exceed the standards required for workmanship in all areas is called 'High quality of workmanship', and using a construction process that does not causes overwhelming workload to the owner's project management staff is 'Minimizes construction aggravation'. The results from 137 qualified responses in the U.S. and U.K. showed that project success is judged based on such criteria as budget variation, schedule variation, and conformity to expectations. These criteria are consistent with the construction industry in general.

Liu and Walker (1998) suggested that a project should be evaluated at two levels. The first level is project goals, which include time, budget, functionality, quality, technical specification, safety, and environmental sustainability. The second level is satisfaction of the claimant. Crane *et al.* (1999) introduced about partnering measures which are result measure, process measure and relationship measure. Among them, result measure is the most important but also difficult to perform. So, they provided an example framework to evaluate results which included cost, schedule, safety, quality, and litigation. Lim and Mohamed (1999) discussed a framework for evaluating project success similar to the framework suggested by Crane *et al.* (1999). Besides time, cost, quality and safety, Lim and Mohamed (1999) added performance and satisfaction to their model. After nearly ten years, environmental impact has become an important index in evaluating project success (Ahadzie *et al.* 2008). Recently, the concept of project success has broadened. The importance of the roles of project schedule, budget, quality, safety, and satisfaction in project success measurement is in no doubt. Al-Tmeemy *et al.* (2011) added four indexes to this framework which are functional requirement, technical specification, revenue and profit and market share.

During a ten year period, from 1990 to 2000, more than twenty studies were conducted to establish project success criteria. The summaries from Chan *et al.* (2002) showed the list of criteria which was used in previous studies as shown in Table 2.7 above. They are separated into objective measures and subjective measures. Related to objective measures, four criteria occurred in most of studies are Time and cost, 'Budget/ Financial performance/ Profitability, Health and Safety, and Quality. Other five measures are Meeting technical performance specifications, Project objectives/ goal attainment, Completion, Functionality, and Productivity/ efficiency, rarely appear. In the subjective measures group, only one criterion, Satisfaction of Client/ Customer, Contractor, and project management team satisfaction, is concerned in almost all studies. Seven other criteria are only mentioned in one or two studies. They are Expectation/aspiration, Dispute resolution satisfaction/conflict management, Absence of conflicts/legal claims, Professional image, Aesthetics, Educational/ social/professional aspects, and Environmental sustainability.

A group of researches concentrated on exploring the important weight and methodology to combine all indexes. They were Griffith *et al.* (1999); Chua *et al*. (1999); Shawn *et al.* (2004); Menches and Hanna (2006); and Shahrzad Khosravi (2011). Although some limitations made them difficult to apply in developing countries, these studies were very important in developing this research framework.

A success indexes equation was developed by Griffith *et al.* (1999). Their equation considered four main criteria with their careful definition. The first criterion was Budget Achievement kept the highest proportion, weight 33% in evaluate project success. It was measured by percent deviation between authorization budget and completion. The second criterion was Schedule Achievement. It weighted 27% in project evaluation and was measured by difference between authorization schedule and actual completion. Two other criteria were Design Capacity and Plant Utilization. They counted 12% and 28% in turn and were measured by authorization and actual attained after six months of operation. Their relative weights were calculated by summing up all responses in important scale. This framework was developed specifically for facility projects. Therefore, it required more indicators and modifications to apply in construction building.

After two years, another group of researchers, Shawn *et al.* (2004), developed a Construction Project Success Survey (CPSS) instrument. Their instrument included classic objective measures such as cost, schedule, quality, performance, safety, and operating environment. They used the seven point Likert scale to score each criterion.

Especially, in their instrument, respondents' perception about how important of each issue was determinated to calculate. However, the instrument which included thirty-two issues related to six groups of criteria as mentioned above with the seven scale of answering made it difficult and confusing for respondents. The result is still subjective because it depends on the perception of respondents.

A quantitative measurement method of successful performance was developed by Menches and Hanna (2006). They provided a process for converting a qualitative evaluation of successful performance to a quantitative measurement. This method is the nearest base for conducting the project success framework in this research. At the end, six factors were selected for the measurement. They were Project profit, Schedule achievement, Amount of time perform the project, Communication among project, Cost achievement, and Change in work time. This method was suitable for contractor's point of view. In the owner's side, these criteria were not enough to cover their entire objective to evaluate project success. However, this research provided an effective method to convert qualitative parameter to quantitative and the concept of probability of successful performance.

From the literature review, there is a wide range of articles focus on the issue of project success. However, these measuring project success models contain some problems.

Firstly, measuring project success model depends on the perception of evaluators (Chan *et al.* 2002). It cannot avoid bias and sensibility. We need a fair, straightforward, unbiased evaluation project success tool. It is necessary to develop a quantitative evaluation project success model.

Secondly, each model was developed based on one party's point of view (Menches and Hanna 2006). One project should satisfy the requirements of all parties such as owners, contractors and consultants or project managers, so project success should be evaluated from them to avoid bias. Owners, contractors and consultants concentrate on the different indexes to evaluate the project. They are also appropriate to provide different information to evaluate project success. Therefore, measuring project success model should let them evaluate the project independently and combine their evaluation to achieve the final project success evaluation.

Thirdly, some quantitative evaluation models are difficult to implement in currently developing countries. For example, in order to evaluate contractor safety performance, they suggested using OSHA assessment, or using Environmental Impact Assessment to evaluate. Therefore, a feasible evaluation of project success should be studied to practice in developing countries. It should consider which index should be used and how to evaluate them carefully based on the real information of completed projects in the quantitative way.

Table 1. Summary List of Indexes, Sub-Indexes and Evaluation Methods from Literature Review

Researchers	List of Indicators and Evaluation Method
Tabish and Jha (2011)	Overall success : Nine-point scale Anti-corruption norms: Nine-point scale Financial norms: Nine-point scale

Researchers	List of Indicators and Evaluation Method
Shahrzad Khosravi (2011)	Time Performance Cost Performance Quality Performance HSE Client Satisfaction
Al-Tmeemy *et al.* (2011)	Quality Targets Schedule Budget achievement Satisfaction of customer Functionality Meeting specification Profit achievement Market development Reputation Competitive Improvement
Ahadzie *et al.* (2008)	Project Cost Project Duration Project Quality Customer Satisfaction Environmental impact
Menches and Hanna (2006)	Profit (0.583) Schedule achievement (0.117): Percent time variation over/underrun Realistic schedule (0.033): How realistic: 1-5 Communication (0.133): Rate how good: 1-5 Achieved budget cost (0.083): Exceed or not: Y/N Work hours (0.05): Percent change in work hours
Bryde and Robinson (2005)	Project Cost (*) Project Duration (*) Technical specification Customer Satisfaction Stakeholders Satisfaction (*)
Chan and Chan (2004)	Time: Construction duration, Construction speed, Schedule variation Project cost: unit Profit: net present value Safety: Accident rate, EIA or ISO 14000 Environmental performance: Number of complaints Quality: Seven-point scale Functionality: Seven-point scale Satisfaction: Seven-point scale
Shawn *et al.* (2004)	Cost: Seven-point scale Schedule: Seven-point scale Quality: Seven-point scale

Researchers	List of Indicators and Evaluation Method
	Performance: Seven-point scale Safety: Seven-point scale Operating Environment: Seven-point scale
Chan *et al.* (2002)	Time: Time overrun, Construction duration, Construction speed Cost: Unit cost, Cost overrun Health and Safety: Accident rate per 1,000 Profitability: Total net revenue over total costs Quality Technical Performance Functionality Productivity Satisfaction Environmental Sustainability
White and Fortune (2002) (General Project)	Project Cost Project Duration Meets client's requirements Organizational objectives Business benefits Quality and Safety requirement
Tukel and Rom (2001) (General Project)	Project Cost Project Duration Technical specification Customer Satisfaction Rework
Chua *et al.* (1999)	Achieve budget target (0.314) Achieve schedule target (0.360) Achieve quality target (0.325)
Lim and Mohamed (1999)	Time Cost Quality Performance Safety Satisfaction
Crane *et al.* (1999)	Cost Schedule Safety Quality Litigation
Griffith *et al.* (1999) (Facility projects)	Budget achievement (0.33): Percent deviation Schedule achievement (0.27): Percent deviation Plant utilization (0.12): Percent of planned utilization and actual attainted after 6 months Design capacity (0.28): Percent of planned utilization and actual

Researchers	List of Indicators and Evaluation Method
	attainted after 6 months
Liu and Walker (1998)	Project goals (1st level): Time, budget, functionality/ quality/ technical specification, safety, environmental sustainability. Satisfaction of the claimant (2nd level) Perception and awareness of different claimant.
Shenhar and Levy (1997) (General Project)	Budget and Schedule: Seven-point scale Customer Satisfaction Business benefits Potential Competition: extend market, new products, and new technology.
Songer *et al.* (1997)	Budget variation, Schedule variation, Conformity to expectations

Research Objective

This paper suggests a practical list of criteria for evaluating success of construction project in developing countries. There are three sources to developing this list of criteria, which are previous research from literature review, information of past projects, and opinion of experts working in construction field. So, it is expected to provide a practicable and applicable list of criteria.

Research Methodology

Data Collection Tools

Before performing the study, a list of indexes and sub-indexes was established. This list was gathered from the literature review and interviews with five experts in construction field. They were more than ten years' of working experience in construction companies and participated in more than five completed projects. The initial list of indexes and sub-indexes with their meaning were described in Table 2 below.

Table 2. List of Indexes and Sub-Indexes used in Feasibility Study

I. Project budget
1. Project budget according to contract
2. Total actual project budget
3. Expenses incurred
4. Sum m^2 of construction floor area
5. Rework costs
6. Budget for contingencies

II. Project **schedule**
1. Planned project duration 2. Actual project duration 3. Speed of construction (Actual duration/floor area) 4. Material availability: Time delay because of supplying materials 5. Equipment availability: Time delay because of lack of equipments 6. Labor availability: Time delay because of lack of labor
III. Project **quality**
1. The different level between quality expectation of owner and real project quality 2. Degree of conformance to predetermined standard 3. Implement the "Evaluate the suitability project quality certificate" in the project 4. Error need to rework when take over the project 5. Information about budget to rework unsatisfied quality requirement works 6. Information about time to rework unsatisfied quality requirement works
IV. Information about **health and safety**
1. Number of death injures or accident 2. Number of heavy accidents 3. Number of slightly accidents 4. Total expenditures for safety management in project 5. Total expenditures to handle and compensate of accidents occur during construction 6. Total time lost due to accident occur 7. Evaluation of safety signs 8. Evaluation of providing safety tools and protection equipment 9. Evaluation safety level of equipment used in construction 10. Evaluation of safety training 11. Evaluation of safety responsibility staffs
V. Information about **technical performance** in project
1. Evaluation of the contractor's response to the technical requirements of project 2. Evaluation of technical problem identification and solution 3. Overall assessment qualifications of workers in the project 4. Evaluation of the possibility of problem solving of technical staff
VI. **Functionality**
1. Evaluation the suitability of project in terms of functionality compared to objectives 2. Evaluation of conformance to expectation
VII. **Productivity**
1. Total number of labor 2. Total labor cost

3. Total equipment cost
VIII. Information about **waste materials** in project
1. Cost of waste primary materials such as steel, coppha, scaffolding,...
IX. **Satisfaction**
1. Owner satisfaction 2. Contractor satisfaction 3. Consultant satisfaction
X. **Environmental sustainability**
1. Frequency of complaints from the environment and communities around the 2. Frequnency of time reminded about sanitation from the authorities 3. The number of time and duration suspended from the authorities 4. Assessing the recovery of the contractor when warned 5. Expenses for ensure environmental sustainability 6. Expenses of overcoming the problems of environmental sanitation
XI. **Communication**
1. Evaluation the communication in project 2. The frequency of misinformation or delays affecting the project 3. Information systems used in project
XII. **Conflicts, litigation, and disputes** in project
1. Evaluation of conflict level about settlement payment 2. Evaluation of conflict level among parties in check and take over the project 3. Evaluation of relationship between contractor and owner after project completed 4. Information about penalties for breach of contract

The first survey is designed to explore the providing information capacity of past projects. An interview questionnaire and document checklist was proposed for data collection at construction companies. It included three main parts. The first part was the general information of visited company. Each company was also asked about its capacity to provide information. The companies demonstrated the number of projects that they promised to provide for the next phase of this research. The second part was the general information of a typical completed project that was provided by each company. The third part was the list of indicators and criteria. The representative engineers, who were familiar with the project, were interviewed, and all of the related project documents were examined to explore providing information capacity. There were three options about providing information capacity for each indicator and criterion, which were “Project has this information and possible to provide information or evaluation opinion”, “Project has this information but difficult to provide information or evaluation opinion”, and “Project does not have this information or cannot provide evaluation opinion”. For the second option, reasons for the difficulty were required to describe.

The second survey is developed to explore the importance and the applicability of each index. The questionnaire included three main sections which were general information about the respondents, importance level, and applicability level. In the first section, the respondents were asked about working company, their position, their age, their experience in the construction field, their academic background, and the number of projects in which they participated. They were also interviewed about their opinion of the necessity of establishing a framework for evaluating project success as the objective of this research. Moreover, they provided their experience in evaluating project success from pass projects. In the second section, respondents expressed their opinion on the importance level of each indicator and criterion in a five point Likert scale. Under categories of "1" means not important at all, "2" means little important, "3" means moderately important, "4" means very important, and "5" means extremely important. In the third section, the applicability of each indicator and criterion was explored by using a five point Likert scale. Under categories of "1" means impossible, "2" means probably not, "3" means chances about even, "4" means probable, and "5" means almost certain.

Data Collection

During January and February 2012, data collection for the first survey was undertaken with construction professionals in Vietnam, at Hochiminh City construction companies. A supporting letter from Hochiminh City University of Technology was prepared and sent to thirty construction companies. As an encouraging sign, twenty-three companies allowed the researcher to visit and agreed to provide information. The cooperation of companies was appreciated. Some companies provided two typical completed projects and two representative engineers. Finally twenty-eight interview questionnaires and document checklists were completed with the cooperation of companies, and the collected information was possible to analyze. To protect the privacy for the visited companies, their names were coded from one to twenty-eight.

The second survey was conducted during February and March 2012 in Vietnam, at Hochiminh City construction companies where the interviewed civil engineers were currently working. From the survey, 125 questionnaires were distributed to ten construction companies (assume ten questionnaires were collected from each company) and twenty-five meetings were held outside these companies. In other to achieve high quality responses, a supporting letter was prepared and sent to these companies and some people before visiting. The interview took approximately thirty to forty-five minutes for each respondent who was willing to contribute opinions. Finally, forty-two questionnaires from the companies and twenty-three questionnaires from the meetings were collected. The other sixty questionnaires were not completed because the engineers in some companies were so busy with their job that they did not have time to fulfill the interview. The total of completed questionnaires was sixty five, and ratio respond was 52.0 percent.

Results

Prior to analyzing and using the sample data, it was important to check for mistakes initially. Data were screened using the complete sample (N = 28) prior to performing the main analyses to examine the accuracy of data entry, missing values, and fit between distributions and the assumptions of necessary analysis tools. All twenty-eight of the samples were possible to be used in general purpose. The data screening process involved a number of steps. The first step was to check for error. The second and third step were to find the error and correct the error in the data file respectively.

Proofreading a random sample was used to ensure the accuracy of the data file. In addition, the Frequencies and Descriptive statistic command in SPSS Version 16 was used to detect any out of range values. None was found.

The following section describes general information in the feasibility study. It includes both company information and project's details. Company information focused on company function, company experience of completed project evaluation, and the number of projects that were ensured to provide. Project's details referred to project type, project budget, project duration, and the source of project capital. With all of the collected information, it was anticipated that the feasibility study was valid and could be a good representative sample.

Stakeholders in the feasibility study were owners, contractors, and consultants. Contractors occupied an important position; comprising more than 60% of the total visited companies. Owner and consultant companies held nearly equal percentages which were 17.86% and 21.43% in turn. It can be seen that all visited companies were representative and an adequate sample of the construction field in Vietnam.

The characteristics of projects in the feasibility study varied greatly. It depended on the convenience to the companies. They provided information on any project that they had just finished and for which all documents were ready to study. This research focused on civil projects, so all twenty-eight projects in the feasibility project were civil projects. Project budget and project duration were also quite varied. Project budgets ranged from US$30,952 to US$227,047,619. Project durations ranged from 90 days to 1095 days. The sources of project capital were also varied, and included public projects, private projects and as well as other types.

This section discusses the availability and submit-ability of information for evaluation of each index and sub-index. As discussed above, each of them was classified according to three groups of responses, which were "Project has this information and possible to provide information or evaluation opinion", "Project has this information but difficult to provide information or evaluation opinion", and "Project does not have this information or cannot provide evaluation opinion". The results of one representative group, information about project budget, are shown in Table 3 below. The summary of probability to collect information of all indexes is shown in Figure 1 below.

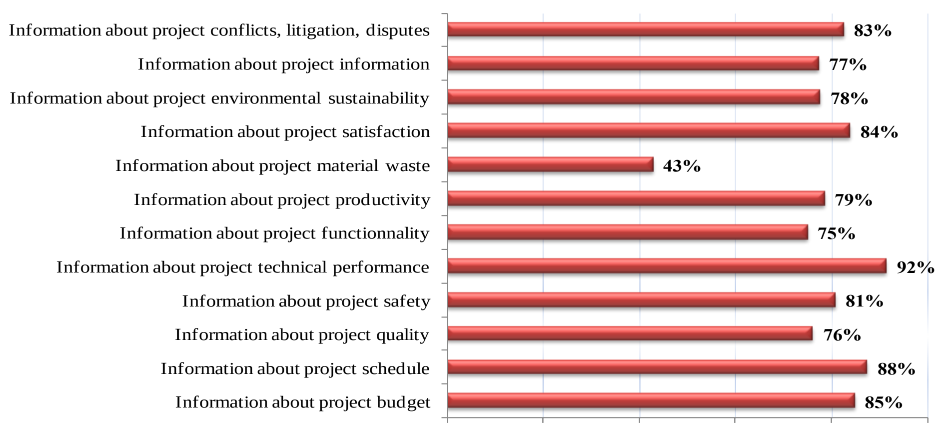

Figure 1. Summary probability of successful collecting information

Table 3. Summary Probability of Successful Collecting Information of a Representative Indexes

Indexes and Sub-indexes	Possible to provide information or opinion evaluation	Difficult to provide information or opinion evaluation	Project does not have this information or cannot evaluate	Probability of successful collecting information
	$P(A/A_1) = 1$	$P(A/A_2) = 0.5$	$P(A/A_3) = 0$	
Information about project budget				**85%**
Budget according to the	100.0%	.0%	.0%	100%
Total actual project budget	85.7%	10.7%	3.6%	91%
Expenses incurred	92.9%	3.6%	3.6%	95%
Sum m2 of floor area	96.4%	3.6%	.0%	98%
Rework Costs	60.7%	14.3%	25.0%	68%
Budget for contingencies	46.4%	21.4%	32.1%	57%

The second survey was developed to explore the importance level and applicability level of indexes and sub-indexes. The respondents were asked to express their opinions and perceptions about that in five point Likert scale of importance level and applicability. To ensure that the items comprising the project evaluation produced reliable scales, Cronbach's alpha coefficient of internal consistency was calculated for each scale. Each scale was compared with the acceptable value of Cronbach alpha of 0.60 (Hair *et al.* 2010). If the value of Cronbach alpha of each scale was higher than 0.60, it was considered acceptable and reliable to analyse the results (Hair *et al.* 2010).

Table 4. Cronbach's Alpha for Project Success Evaluation Indexes (N = 65)

Cronbach's alpha	N of Items	Importance Scale	Applicability Scale
Project budget scale	6	0.684	0.707
Project schedule scale	6	0.739	0.785
Project quality scale	6	0.819	0.800
Project health & safety scale	11	0.887	0.872
Project technical performance scale	4	0.827	0.847
Project functionality scale	2	0.741	0.750
Project productivity scale	3	0.921	0.914
Project satisfaction scale	3	0.837	0.833
Project environmental sustainability scale	6	0.837	0.792
Project communication scale	3	0.642	0.740
Project conflicts, litigation, and disputes scale	4	0.831	0.818

The results of both the importance level and the applicability level of all sub-indexes were shown in Figure 6 and Figure 7 below. The hypothesis testing was applied to compare their means with the average value. Testing results showed that all criteria were important and applicable at 95% confidence.

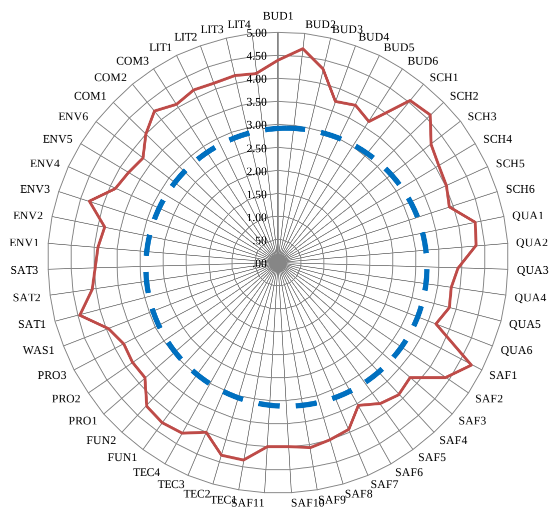

Figure 6. Mean of importance level of each index and sub-index (N=65)

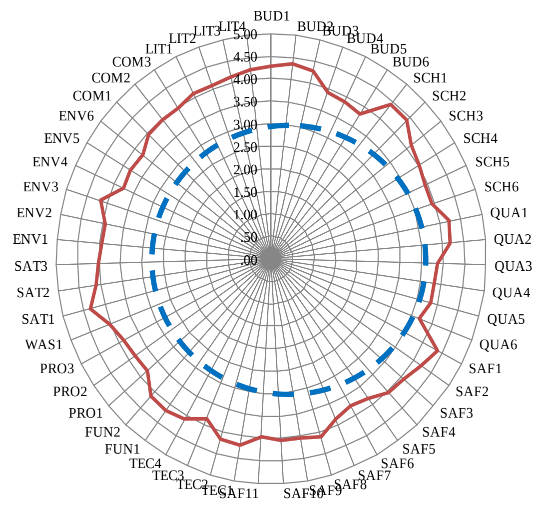

Figure 7. Mean of applicability level of each index and sub-index (N=65)

The scatter plot in Figure 8 and Figure 9 below demonstrated the combination results between the probability of information collecting and their importance level, or their applicability level. These values dispersed clearly into two groups, which were upper and lower 60% of probability value. Therefore, there were three criteria for making decision in which index and sub-index are used for evaluating project success. First, that index had a high probability to collect information, meaning that the probability of successful collecting information was higher than 60%. Second, that index was important from the respondents' perception; mean of importance level was higher than three. Third, that was an applicability index with mean value also higher than three. The results of decision making of accept or reject these indexes and sub-indexes were showed in Table 4.

The results in Table 5 below pointed out seven sub-indexes could not be used in evaluating project success. The rejected sub-indexes were 'Budget for contingencies', 'Budget to rework unsatisfied quality requirement works', 'Total expenditures for safety management in project', 'Total expenditures to handle and compensate of accidents occur during construction', 'Total time lost due to accident occur', 'Evaluation of conformance to expectation', and 'Waste material in construction site'. These sub-indexes were under Budget, Quality, Safety, Functionality, and Waste material indexes. They were rejected because they were considered difficult to collect information, their probability of successful collecting information were 57%, 57%, 48%, 46%, 59%, 59%, and 43% in turn, lower than 60% of critical value.

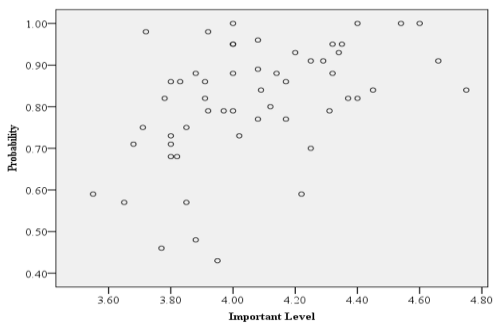

Figure 8. Scatter plot between probability of successful collecting information and mean of importance level

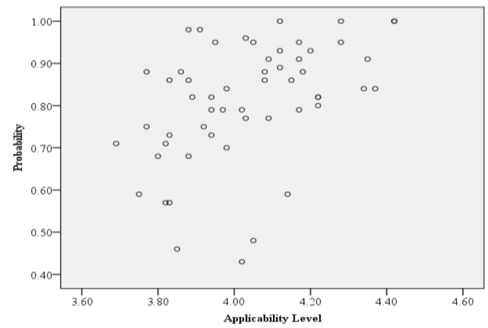

Figure 9. Scatter plot between probability of successful collecting information and mean of applicability level

The final proposed criteria of construction project success evaluation framework is described in Figure 10. In this framework, eleven indexes are suggested to evaluate project success. These indexes focus to evaluate four main classic targets of construction project such as project cost, project time, project quality and safety. In addition, project also can be evaluated its success by assessing technical performance, its functionality, construction productivity, project stakeholder’s satisfaction, assessing from surrounding environment, communication, litigation and disputes occurring during construction time. In order to evaluate these indexes, a sub-system includes forty six sub-indexes is described in Figure 10.

Table 5. Summary Results to Select Criteria of Construction Project Success

Variable code	Probability of successful collecting information	Mean of Importance Level	Mean of Applicability Level	Decision
BUD1	100%	4.40	4.28	Accept
BUD2	91%	4.66	4.35	Accept
BUD3	95%	4.32	4.28	Accept
BUD4	98%	3.72	3.91	Accept
BUD5	68%	3.80	3.88	Accept
BUD6	57%	3.65	3.82	**Reject**
SCH1	100%	4.54	4.42	Accept
SCH2	100%	4.60	4.42	Accept
SCH3	93%	4.20	4.12	Accept
SCH4	77%	4.08	4.03	Accept
SCH5	73%	4.02	3.94	Accept
SCH6	82%	3.91	3.94	Accept
QUA1	82%	4.37	4.22	Accept

Variable code	Probability of successful collecting information	Mean of Importance Level	Mean of Applicability Level	Decision
QUA2	88%	4.32	4.18	Accept
QUA3	86%	3.91	3.88	Accept
QUA4	73%	3.80	3.83	Accept
QUA5	57%	3.85	3.83	**Reject**
QUA6	71%	3.68	3.69	Accept
SAF1	84%	4.75	4.37	Accept
SAF2	82%	4.40	4.22	Accept
SAF3	86%	3.80	4.08	Accept
SAF4	48%	3.88	4.05	**Reject**
SAF5	46%	3.77	3.85	**Reject**
SAF6	59%	3.55	3.75	**Reject**
SAF7	98%	3.92	3.88	Accept
SAF8	100%	4.00	4.12	Accept
SAF9	96%	4.08	4.03	Accept
SAF10	95%	4.00	4.05	Accept
SAF11	95%	4.00	3.95	Accept
TEC1	93%	4.34	4.20	Accept
TEC2	95%	4.35	4.17	Accept
TEC3	88%	4.00	3.86	Accept
TEC4	91%	4.25	4.09	Accept
FUN1	91%	4.29	4.17	Accept
FUN2	59%	4.22	4.14	**Reject**
PRO1	68%	3.82	3.80	Accept
PRO2	86%	3.83	3.83	Accept
PRO3	82%	3.78	3.89	Accept
WAS1	43%	3.95	4.02	**Reject**
SAT1	84%	4.45	4.34	Accept
SAT2	89%	4.08	4.12	Accept
SAT3	79%	3.97	4.02	Accept
ENV1	79%	3.92	3.94	Accept
ENV2	75%	3.85	3.92	Accept
ENV3	79%	4.31	4.17	Accept
ENV4	88%	3.88	3.77	Accept
ENV5	71%	3.80	3.82	Accept

Variable code	Probability of successful collecting information	Mean of Importance Level	Mean of Applicability Level	Decision
ENV6	75%	3.71	3.77	Accept
COM1	79%	4.00	3.97	Accept
COM2	70%	4.25	3.98	Accept
COM3	84%	4.09	3.98	Accept
LIT1	77%	4.17	4.09	Accept
LIT2	88%	4.14	4.08	Accept
LIT3	86%	4.17	4.15	Accept
LIT4	80%	4.12	4.22	Accept

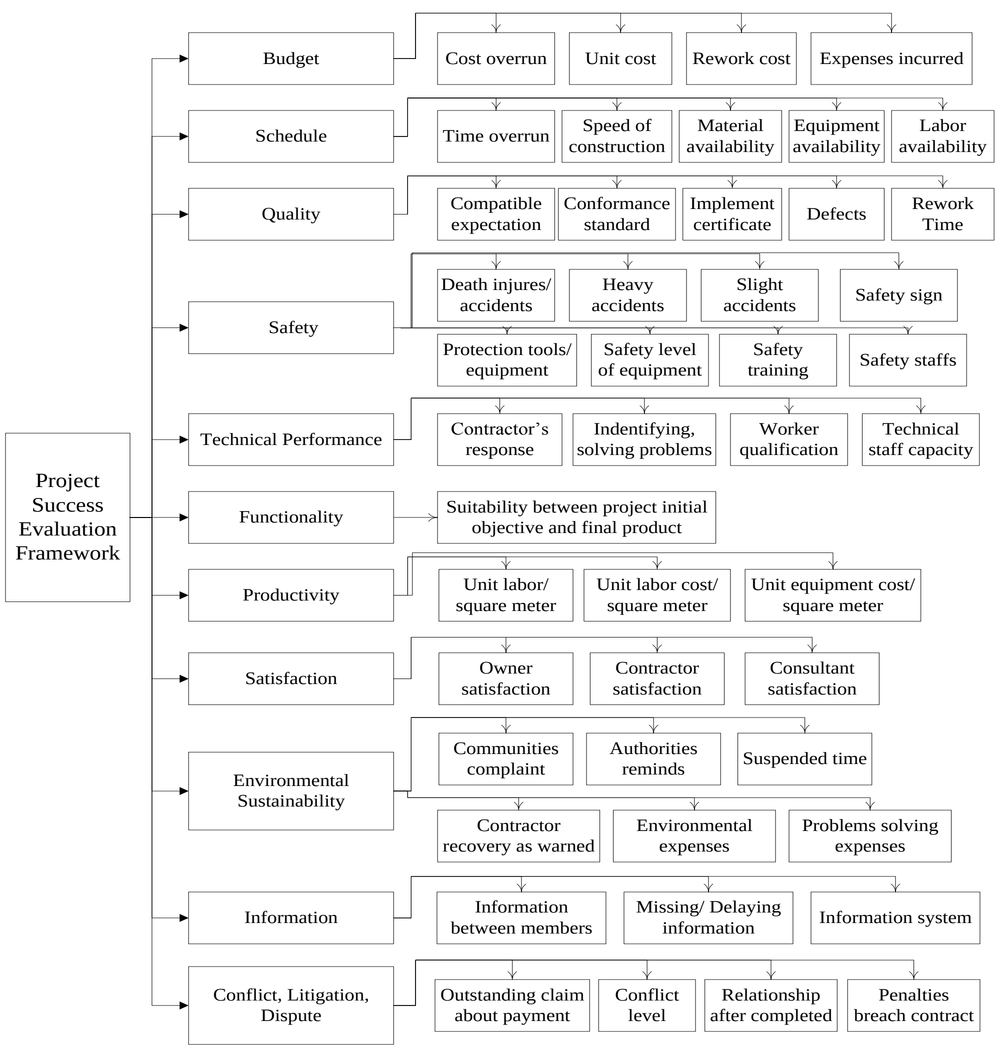

Figure 10. Proposed criteria of project success evaluation framework

Conclusions

This paper described a process to establish the final list of indexes and sub-indexes of construction project evaluation. It was achieved after conducting feasibility study, importance and applicability study. The initial twelve indexes and fifty-three sub-indexes were accessed. The final indexes and sub-indexes in this list had to satisfy three criteria, which are high capacity to collect information, high level of importance, and high degree of applicability to evaluate project success.

To achieve this objective, two surveys were performed. The first survey collected information from twenty-eight completed projects to consider the capacity to collect necessary information to evaluate project success. The second survey gathered opinions from sixty-five respondents about the importance level and applicability level of each index and sub-index. From analysis results, one index and seven sub-indexes were eliminated from the list. The final list included eleven indexes which were clearly described by forty-six sub-indexes.

This paper provided an innovative practical list of indexes and sub-indexes for project evaluation. Although there are many models from previous studies to evaluate project success, the list in this paper has contributed additional components. List of indexes and sub-indexes was developed from three sources, which were the literature review (theory), previous documents of completed projects (industrial sources), and experts and respondents (academic and human opinions). Therefore, it was fully representative and objective. The list of indexes and sub-indexes were ensured that they could be evaluated by real information when project completed. It helps to overcome the limitations of previous studies in practical evaluation.

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